IMPACT OF FIRE ON RECREATION STREAM WATER QUALITY AND SPAWNING HABITAT

FINAL REPORT

Impact of Fire on Recreation Stream Water Quality and Spawning Habitat

Submitted to:

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Introduction

The purpose of this study is to determine how the benthos of tributary streams to the Middle Fork of the Salmon River have responded to a fire. The study includes a characterization of stored organic material in sediments and benthic fauna, and relates fire intensity, basin morphometry and stream velocity-discharge to the distribution and abundance of benthic invertebrates.

The Mortar Creek fire on the Middle Fork of the Salmon River, Idaho began on July 25, 1979 and was declared out on August 20, 1979. It burned more than 26,000 ha. In burned watersheds, fire intensity varied from small to severe and reached an estimated 30,000 BTU/s/ft (Byrams Intensity; Personal Communication to J.T. Brock) in several severely burned basins. Specific information concerning precise fire distribution and intensity within each of the burned watersheds has not e been released by the U.S. Forest Service. Overall, the burned areas extended along 40 km of the Middle Fork of the Salmon (Fig. 1).

The general approach for this study was to use watersheds of varying sizes and which had been subject to varying burn intensities. Sites selected for the summer intensive survey included those selected by Minshall, et al. (1981); specific watersheds (Fig. 1) were chosen to emphasize the contrast between burn and unburned (control) sites. Sampling was initiated on July 22, 1982. All sites were visited and samples taken over a 12 day period.

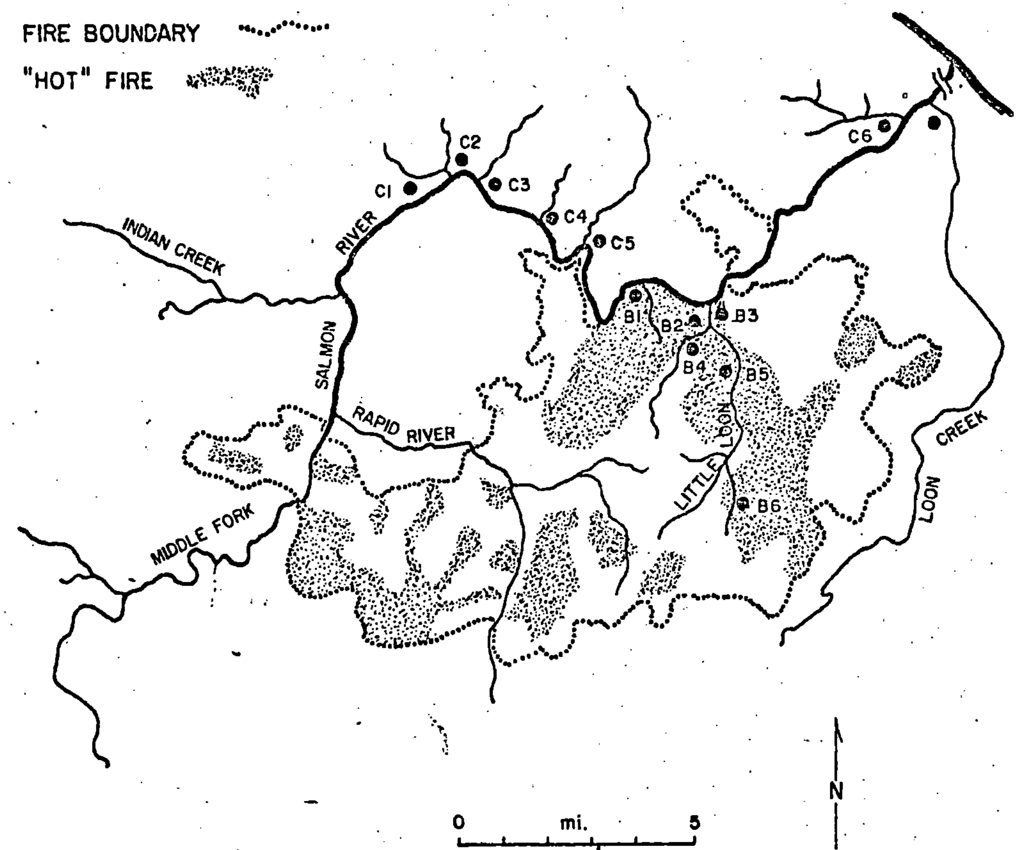

Figure 1. Map of Mortar Creek Fire sample sites, Middle Fork of the Salmon River, Idaho. Stippled areas are visually apparent "hot burns".

Description of the Study Area

The Middle Fork of the Salmon River runs through central Idaho within (for the most part) the River of No Return Wilderness Area. The area is pristine with few human inhabitants. Primary river use is recreational; rafting during the summer months is popular and restricted to the main river.

The topography is extremely rugged with elevations ranging from 3150 m, above the headwaters, to 975 m on the confluence of the Middle Fork and the Salmon River. Tributary streams have high to medium gradients with steep side slopes. The Middle Fork of the Salmon drainage basin is underlain by Challis Volcanics which have been intruded by various phases of Idaho Batholith. Challis volcanics are comprised of rhyolitic to andesitic tuffs of Eocene age (Cater et al. 1973, Knowles and Bennett 1978). The Idaho Batholith is a pluton of granodiorite and quartz monzonite with lesser amounts of Cretaceous diorite.

Streamsites examined during this study lie in a mixture of Idaho Batholith and Challis Volcanics rocks. The geological conditions are complex with most drainages underlain by several parent rock types (Table 1).

Precipitation in the area is largely in the form of snow. At higher elevations, snow begins to accumulate in late October and early November. Snow remains on the ground until late April and May. Summer thunderstorms can deliver substantial volumes of water within a short period of time in tributary watersheds. Volume of rainfall has ranged from 38 to 50 cm in the valleys to 76 to 100 cm near the peaks (Minshall

Table 1. Drainage basin characteristics of Mortar Creek Fire Study sites listed in order of downstream distance along Middle Fork from Dagger Falls. From Minshall, et al. 1981.

Site	Type C=Control B=Burn	Longitude	Latitude	River Distance from Dagger Km	Drainage Area Km^2	Drainage Aspect	Maximum Stream Elev. in Drainage m	Station Elevation m	Drainage Rock Type
M Fk Dagger	C	115°16'59"	44°31'43"	0	-	NW	2623	1768	Batholith (quartz monzonite, granite)
M Fk above Indian Ck	B	115° 6'33"	44°45'29"	40.4	-	NE	2623	1426	Batholith (quartz monzonite, granite)
Indian Ck	C	115° 6'27"	44°46' 2"	42.6	212.7	SE	2318	1414	Volcanics, quartz monzonite
East Fk Indian Ck	C	115° 5'32"	44°46'15"	42.6	17.3	SW	2318	1413	Volcanics
Pungo Ck	C	115° 4'21"	44°45'56"	44.6	13.8	S	2318	1396	Quartzite, granite, volcanics
Teapot Ck	C	115° 2'37"	44°45'10"	45.9	2.9	S	2342	1390	Granite, quartzite
Marble Ck	C	115° 1' 0"	44°44'38"	51.5	298.8	S	2623	1344	Volcanics, granite
Little Ck	B	114°59'31"	44°43'11"	56.0	5.1	NW	2403	1408	Quartz monzonite, granite
M Fk at Little Ck Bridge	B	114°59'53"	44°43'27"	56.0	1,990	NE	2623	1311	
Little Loon Ck	B	114°56'17"	44°43'45"	63.6	86.5	NW	2562	1286	Granite, quartz, diorite, volcanics
Char	B	114°56' 8"	44°42'31"	63.6	3.2	NE	2342	1356	Granite
West Fk Little Loon Ck	B	114°56' 3"	44°42'35"	63.6	20.7	NE	2446	1341	Granite, quartzite, dacite
East Fk LIttle Loon Ck	B	114°55'58"	44°42'35"	63.6	84.0	NW	2562	1329	Granite, quartz, diorite, volcanics
White Ck	C	114°50'39"	44°47'29"	76.3	11.3	SE	2330	1244	Granite, volcanics
M Fk above Loon Ck	B	114°48'43"	44°48'26"	80.0	-	NE	2623	1219	
Loon Ck	C	114°48'35"	44°48'25"	80.0	-	NW	2623	1219	Granite, quartz monzonite, volcanics
M Fk at Mouth	B	114°35'40"	45°17'44"	155.3	-	NE	2623	914	

et al. 1981).

Predominant vegetation types in the Middle Fork drainage basin vary with elevation. At higher elevations, subalpine fir (Abies lasiocarpa) and whitebark pine (Pinus albicaulus) predominate. Douglas fir (Pseudotsuga menziesii) and aspen (Populus tremuloides) cover wooded slopes at mid- to lower elevations; Ponderosa pine (Pinus ponderosa) grows at low elevations along the mainstem. Riparian vegetation along tributaries can be very dense in certain watersheds; it is composed primarily of alder (Alnus spp.), willow (Salix spp.), water birch (Betula spp.) and cottonwood (Populus balsamifera). Grasses, sagebrush (Artemisia spp.) and mountain mahogany (Cercocarpus spp.) are are found at middle and lower elevations on drier, south facing slopes.

Methods and Materials

General Stream Characteristics

General site characteristics including drainage area, drainage aspect and sample site elevation are listed in Table 1. Specific physical and hydraulic characteristics of each site are listed in Table 2. Stream order (Strahler 1952) and stream link (Gregory and Walling 1973) are measures of stream size. Smaller streams generally have higher slopes ranging from 1 to 8.2 percent, larger tributaries have slopes in the range 1 to 4 percent, and the mainstem (Middle Fork) has a slope varying from 1 to 3 percent.

Substrate Permeability

A standpipe corer ("Mark VI Groundwater Standpipe"; Reiser and Wesche 1977) was used to derive an index of substrate permeability. The

Table 2. Channel characteristics of Mortar Creek Fire study sites, summer 1982.

	TYPE C=control B=burn M=mainstem	STREAM ORDER	STREAM LINK	CHARACTERISTIC SUBSTRATE SIZE, CM	SLOPE AT STATION DEGREE	WIDTH, M	MEAN DEPTH, M	MEAN VELOCITY M/SEC	DISCHARGE, M^3/SEC
MF above Indian Ck	M	6	1218	5-100	1% (est)	52.5	0.99	1.40	74.82
Indian Ck	C	4	89	2-30	2	17.2	0.29	0.91	4.61
East Fk Indian Ck	C	3	12	2-8	3.5	2.7	0.11	0.36	0.065
Pungo Ck	C	2	10	30-40	7.5	2.6	0.10	0.54	0.100
Teapot Ck	C	1	1	5-15	8.2	1.7	0.24	0.32	0.022
Marble Ck	C	5	262	15 (est)	0.25	20.6	0.06	0.65	3.390
Little Ck	B	2	7	5-10	3.5	3.6	1.06	0.44	0.036
MF at Little Ck Bridge	M	6	1615	150+	1% (est)	45.0	0.22	1.45	78.20
Little Loon Ck	B	5	132	10-80	3	5.9	0.31	0.76	1.283
East Fk Little Loon Ck	B	4	105	10-50	1°10'	5.5	0.10	0.90	1.099
West Fk Little Loon Ck	B	4	24	5-60	4	3.8	0.04	0.40	0.281
Charcoal Ck	B	2	2	2-8	7	3.0	0.08	0.28	0.022
White Ck	C	4	24	2-15	3°40'	2.8	0.45	0.27	0.061
Loon Ck	C	6	903	10-50	1.5	30.2		0.82	12.34

* Estimated

rate at which water enters the standpipe (Fig. 2) from the surrounding sand and gravel has been used as a variable determining the suitability of particular gravel beds for spawning (Terhune 1958, Turnpenny and Williams 1982). The principle of operation is simple: if many "small" particles (e.g., silt) are found within a gravel bed, the available pore space is less, making available less intra-gravel flowing water. Fine particles clog the 3 mm diam holes at a rate proportional to their concentration within the substrate. Five replicate cores were measured at each of the study sites.

Chemical

Water samples were filtered through a 0.45 µm membrane filter in the field; the filtrate was used to fill four 250 ml bottles. Each bottle was preserved differently depending upon the analysis to be performed (Table 3). All bottles were refrigerated on ice until analysis. Alkalinity was determined titrimetrically using a Gram titration (Talling 1973). Sulfate and fluoride were measured with a Dionex System 14 ion chromatograph. Operating conditions for this instrument were set at 30 µmho full scale reading, and 250 psi. The eluent was 0.0024 M Na_2CO_3 on a short separator column, with an on-line supressor column. Chloride was determined spectrophotometrically using a Mercury (II) - thiocyanate method (Florence 1971).

The cations Ca^{2+}, Mg^{2+}, Na^+ and K^+ were determined using a Perkin-Elmer model 403 atomic absorption spectrophotometer. Operating conditions for the instrument are as established by the manufacturer (Perkin-Elmer 1973).

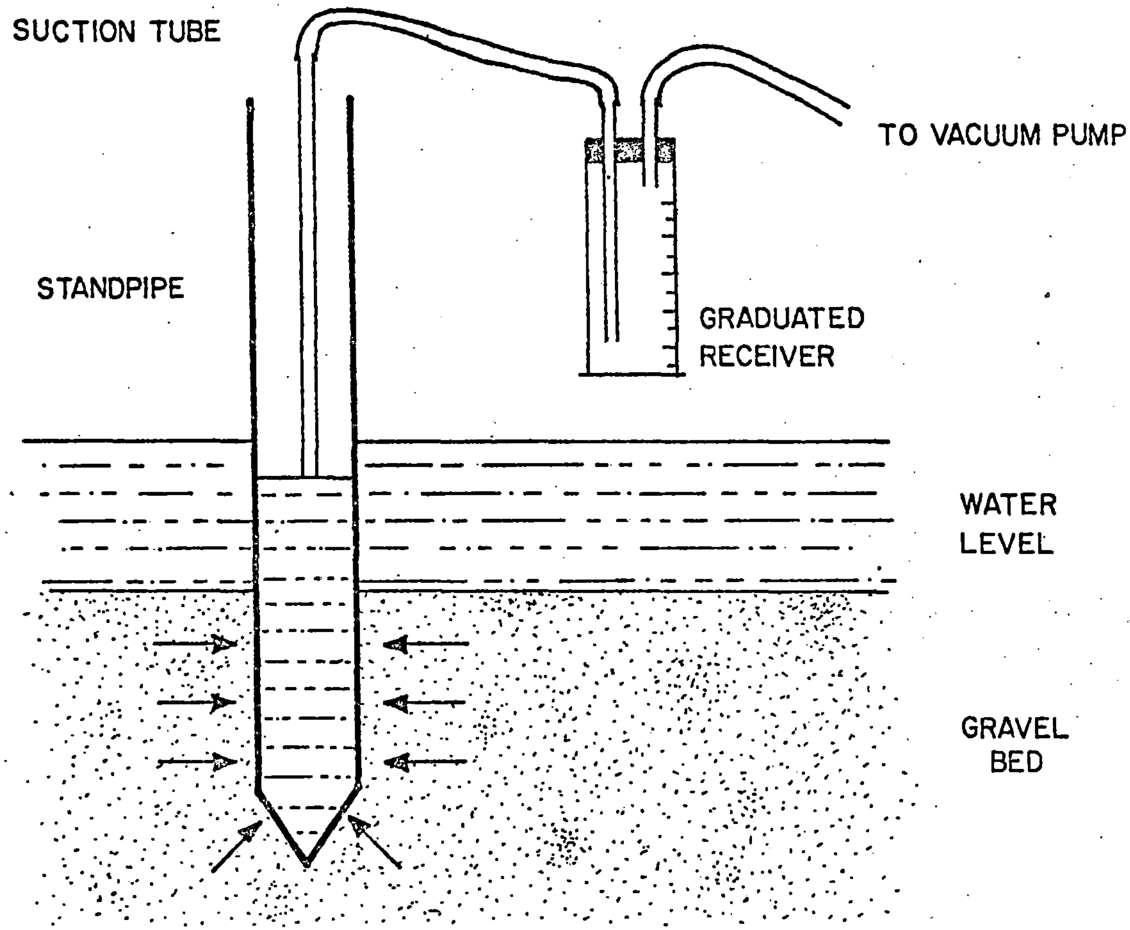

Figure 2. Mark VI standpipe corer. See text for explanation.

Table 3. A summary of the chemical processing which occurred subsequent to filtering water samples through 0.45 μm membrane filters.

METHOD OF PRESERVATION	CHEMICAL ANALYSIS	METHOD OF ANALYSIS	REFERENCE
1. Refrigeration	Alkalinity Chloride	Titrimetric Spectrophotometric	Florence, 1971
2. Add HNO_3 to pH $\leq$ 2.0; refrigerate.	Calcium Magnesium Sodium Potassium	Atomic Absorbtion " " "	Perkin Elmer
3. Add H_2SO_4 to pH $\leq$ 2.0; refrigerate.	Phosphate Nitrate	Spectrophotometric Ion Chromatograph	Riley, 1958
4. Add HgCl to approximately _______ mg/l; refrigerate.	Sulfate Fluoride	Ion Chromatograph "	Dionex

Conductivity was measured in the field with a YSI model 32FL temperature compensating field conductivity meter. Stream water pH was also measured on-site using a Coleman null-balance pH meter.

All chemical data collected were designated into one of three site classifications: control streams, burn streams and mainstem (Table 4). Comparisons of ion concentrations among burn and control streams always used data from all 33 locations listed under "Burn" and "Control" in Table 4. However, similar comparisons for ion yield (in mass/$km^2 \cdot$day) used only the eleven sites marked with asterisks, for these were the only burn and control sites for which data on ion concentration, drainage area and discharge are available. More than one analysis was performed for several ions at certain sites. However, for statistical analyses, all replicates from one site were averaged to yield a single value for each ion at each site. Whenever an ion analysis yielded a concentration below the limit of it's detection, for computational purposes the concentration of that ion was arbitrarily set to one-half the detection limit, rather than zero.

<u>Transported and Stored Organic Material</u>

Organic material, both that stored within the sediments and that transported in the water column was collected at each of the sampled tributaries. The collected material was treated as outlined in Table 5. Collected material was separated into two size fractions in the field, coarse (> 1 mm) and fine (> 0.052 mm $\leq$ X $\leq$ 1.00 mm). Dissolved organic carbon was sampled by collecting water filtered through Gelman GF/F tared glass fiber filters.

Benthic stored material was characterized qualitatively by visual

Table 4. Names of the study sites grouped into three types. The sites marked with an asterisk are those used in the analyses of ion yield. Also indicated is the link number of each stream site.

CONTROL		BURN		MAINSTEM	
NAME	LINK	NAME	LINK	NAME	LINK
Pistol Ck	93	Greyhound Ck	6	M Fk Dagger	559
Indian*	89	Rapid R	249	M Fk Rapid	767
E Fk Indian*	12	Mortar Ck	1	M Fk Indian	1217
Pungo Ck*	10	P B R Ck	1	M Fk Pungo	1307
Teapot Ck*	1	L Soldier Ck	7	M Fk Marble	1335
Marble*	262	Thomas Ck	11	M Fk Sunflower	1597
Cameron Ck	3	Little Ck*	7	M Fk Little*	1615
Pine Ck	13	Jackass Ck	3	M Fk L Loon	1645
Foundation Ck	1	L Loon Mouth*	132	M Fk Pine	1817
White Ck*	24	E Fk L Loon*	105	M Fk Loon	1887
Loon Ck	903	W Fk L Loon*	24	M Fk Mouth	5412
M Fk Camas	2924	Char Ck*	2	Main Salmon M Fk	6721
Camas Ck	893	Huntoon's Leak	1		
Big Ck	940	Fig Nancy Sp	1		
M Fk Big Ck	4193	Cougar Ck	22		
		Ship Island Ck	23		
		Burnt Tree Ck	1		
		Tumble Ck	6		

Table 5. Summary of study parameters, sampling methods, and analytical procedures for evaluating the effects of the Mortar Creek fire on streams in the Middle Fork drainage of the Salmon River, Summer 1982.

Parameter	Sampling Method	Analytical Methods
1. Discharge	Velocity-depth profiles; Price or Ott Cyrrent Meters; established transects.	
2. Temperature	Maximum-minimum recording thermometers at all stations.	
3. Water Quality	Composited "grab" samples	
pH		Coleman Null-balance meter
Conductivity (TDS)		Beckman Wheatstone Bridge
Alkalinity		Gran Titration
Dissolved Carbon		Oceanography International Carbon Analyzer
Ca,Mg,Na,K,Ck,N,P		Atomic Absorption Spectrophotometer Standard Methods, 1975
4. Transport (materials carried in suspension by stream)		
Quantity Partitioned into 3 particle sizes.	>1 mm River - conical net with flowmeter 0.052-1.0 mm Tributaries - siphon hose and net. <0.52 mm Depth integrating sampler, field filtration onto tared glass fiber filters.	Dried at 60°C, weighed; combusted at 525°C, reweighed.
Quality % organic	Same as above.	Ash-free dry weight - total dry weight determined as above.
5. Redd Permeability	Standpipe driven into redd to a depth of 8-10 cm, pumped dry and time taken to re-fill recorded.	Mark VI groundwater standpipe with pumping apparatus.
6. Storage (materials deposited on stream bottom)		
Total	>1 cm: "pebble counts" 0.05 mm - 1 mm: volume-weight of materials vacuumed from known area along a transect.	Imhoff Cones; Volumes converted to weights using regression equations.
Organic	Qualitative sample for % organic matter	Partitioned into 3 particle sizes. Dried at 60°C, weighed, combusted at 525°C, reweighed. Convert to amount from knowledge of total weight. Calculate inorganic portion by difference.
Inorganic		
7. Benthic Organisms (Invertebrates and associated detritus)	Collect 5-10 similar-sized cobble stones at each site with fine-meshed dip net.	Measure length, and thickness of rocks. Separate invertebrates into functional groups, count and weight (or measure length). Determine AFDM of detritus.
Periphyton Standing Crops	Scrape known area of rocks; collect scrapings on filter.	Determine Chlorophyll by spectrophotomery and AFDM.

examination, percent organic composition and chlorophyll concentration.

Inorganic Sediments

Fine (0.05 - 1.00 mm) sediments were sampled using a diaphragm (Guzzler) suction pump with an intake nozzle of known (10 cm) diameter. Five cores were taken at random at each of the burn and control stream sites. During each collection, the pump was operated until all fine material was removed from the sample spot. Collected samples were elutriated into separate organic and inorganic components. Volumes of each component were measured using Imhoff cones.

Benthic Organisms

Benthic invertebrates were collected using a fine mesh (52 μm) net placed downstream from cobble or larger stones. Stones were lifted and scrubbed into the net; the underlying substrate was stirred to dislodge all associated organic debris and resident invertebrate species.

Results

Chemical

Chemistry data, as means of replicate data, obtained from each sampling location are listed in Table 6. Comparisons among burn and control streams using mean ion concentrations show that in seven of 10 cases, burn streams have higher concentrations (Table 6).

A Pearson product-moment correlation (SPSS, Nie, et al. 1975) matrix for ion concentration (Table 7), obtained using all data, reveal several interesting inter-relations. First, stream order and stream link number (both measures of stream size) are positively, significantly

Table 6. Average ion concentrations ± standard deviation found at three types of study sites, and for all study sites combined. Except as noted, units are meq/l.

ION	CONTROL	BURN	MAINSTEM	ALL
Ca	0.860 ± 0.59	0.850 ± 0.337	0.537 ± 0.159	0.767 ± 0.429
Mg	0.145 ± 0.099	0.164 ± 0.093	0.104 ± 0.082	0.142 ± 0.097
Na	0.196 ± 0.125	0.175 ± 0.074	0.136 ± 0.061	0.171 ± 0.094
K	0.021 ± 0.009	0.021 ± 0.009	0.016 ± 0.006	0.020 ± 0.009
Alk	1.146 ± 0.744	1.118 ± 0.445	0.746 ± 0.243	1.022 ± 0.554
SO_4	0.076 ± 0.062	0.090 ± 0.062	0.053 ± 0.046	0.076 ± 0.061
Cl	0.018 ± 0.021	0.025 ± 0.020	0.012 ± 0.016	0.019 ± 0.020
F	0.023 ± 0.018	0.011 ± 0.009	0.014 ± 0.005	0.015 ± 0.012
PO_4 (mg/l)	0.011 ± 0.009	0.054 ± 0.065	0.010 ± 0.010	0.028 ± 0.046
NO_3 (mg/l)	0.398 ± 0.671	0.814 ± 0.941	0.025 ± 0	0.465 ± 0.768

Table 7. Summary of the Pearson product-moment correlation matrix for ion concentration. All data were used in the analysis. A "significant correlation" is one which is significant at $p \leq 0.05$. For each combination in the table the data are (Number of significant correlation)/(Total number of possible correlations). Also indicated are the variables for which the correlations were not significant (Cond=conductivity; Alk=Alkalinity; S=Sulfate; P=phosphate; N=Nitrate; x·yz means variable x was not significantly correlated with y or z). For selected cases the value of the correlation coefficient is enclosed in parentheses. Neg indicates significant negative correlation coefficient(s) in those cases where a signed value is not provided.

	Area of Drainage Basin	Volume Discharge	Order	Link	Log (link)	Cations	Anions	PO_4^{3-} plus NO_3^-	Conductivity
Area of Drainage Basin	-	1/1 (.99)	1/1 (.61)	1/1 (.997)	1/1 (.69)	1/4 Ca,Mg,Na,K	2/4 Alk,F	0/2 P,N	0/1 Cond.
Volume Discharge	1/1 (.99)	-	1/1 (.58)	1/1 (.82)	1/1 (.64)	3/4 Na,Neg	3/4 F,Neg	0/2 P,N	1/1 (-.49)
Order	1/1 (.61)	1/1 (.58)	-	1/1 (.70)	1/1 (.98)	4/4 Neg	3/4 F,Neg	1/2 P,Neg	1/1 (-.50)
Link	1/1 (.997)	1/1 (.82)	1/1 (.70)	-	-	0/4 Ca,Mg,Na,K	0/4 Alk,S,Cl,F	1/2 P,neg	0/1 Cond.
Log (link)	1/1 (.69)	1/1 (.64)	1/1 (.98)	-	-	4/4 Neg	3/4 F,Neg	2/2 Neg	1/1 (-.44)
Cations	0/4 Ca,Mg,Na,K	3/4 Na,Neg	4/4 Neg	0/4 Ca,Mg,Na,K	4/4 Neg	6/6	15/16 K	8/8	4/4
Anions	2/4 Alk,F	3/4 F,Neg	3/4 F,Neg	0/4 Alk,S,Cl,F	3/4 F,Neg	15/16 K	6/6	7/8 F	3/4 F
PO_4^{3-}	0/1 P	0/1 P	0/1 P	0/1 P	1/1 (-.24)	4/4	3/4 F	1/1 (.56)	1/1 (.39)
NO_3^-	0/1 N	0/1 N	1/1 (-.36)	1/1 (-.31)	1/1 (-.57)	4/4	4/4	1/1 (.56)	1/1 (.50)
Conductivity	0/1 Cond.	1/1 (-.49)	1/1 (-.50)	0/1 Cond.	1/1 (-.44)	4/4	4/4	2/2	-

correlated (r = 0.70). However, when link number is plotted against stream order (Fig. 3), an exponential relationship rather than linear is suggested. Log (link number) used in the Pearson correlation improves the correlation value to 0.98.

Second, discharge, order and log (link number) are significantly correlated with the concentrations of several ions. This suggests these measures of stream size should be controlled for when evaluating differences in ion concentration stemming from the burn.

Third, a variety of correlations involving physical parameters were, a priori, expected to be significant and were found to be so: 1) drainage basin area and measures of stream size (e.g., order, link number and discharge); 2) all possible combinations of stream size measures; 3) conductivity, with alkalinity and discharge (negatively). Finally, several other expected, significant correlations occurred: 4) among almost all possible ion concentration combinations; 5) conductivity and the concentrations of all ions; and 6) between discharge and (negatively) the concentrations of anions and cations.

To make a visual comparison for differences among the relative compositions of major ions among burn, control and mainstem sites, we constructed four trilinear graphs (Fig. 4). The trilinear graphs depict concentrations on a percentage basis and illustrate relative rather than absolute chemical composition of water. The relative composition at all sites was similar; calcium and bicarbonate/carbonate ions are predominant. Relative amounts of sodium, potassium and chloride are small.

Several factor analyses were run using the BMDP program package

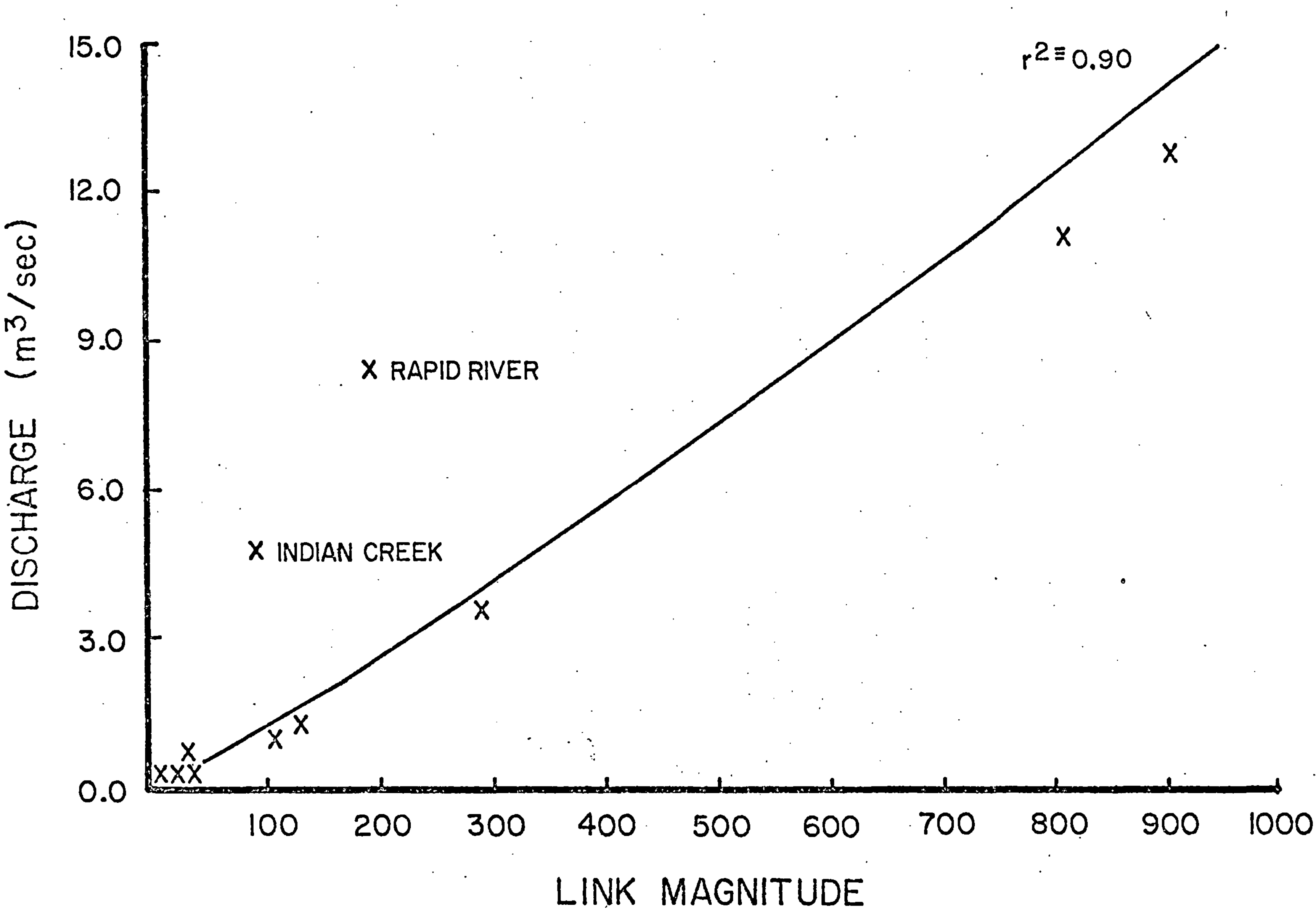

Figure 3. Stream discharge as a function of link number (magnitude). Linear regression, r=0.90; Loglinear regression, r=0.98.

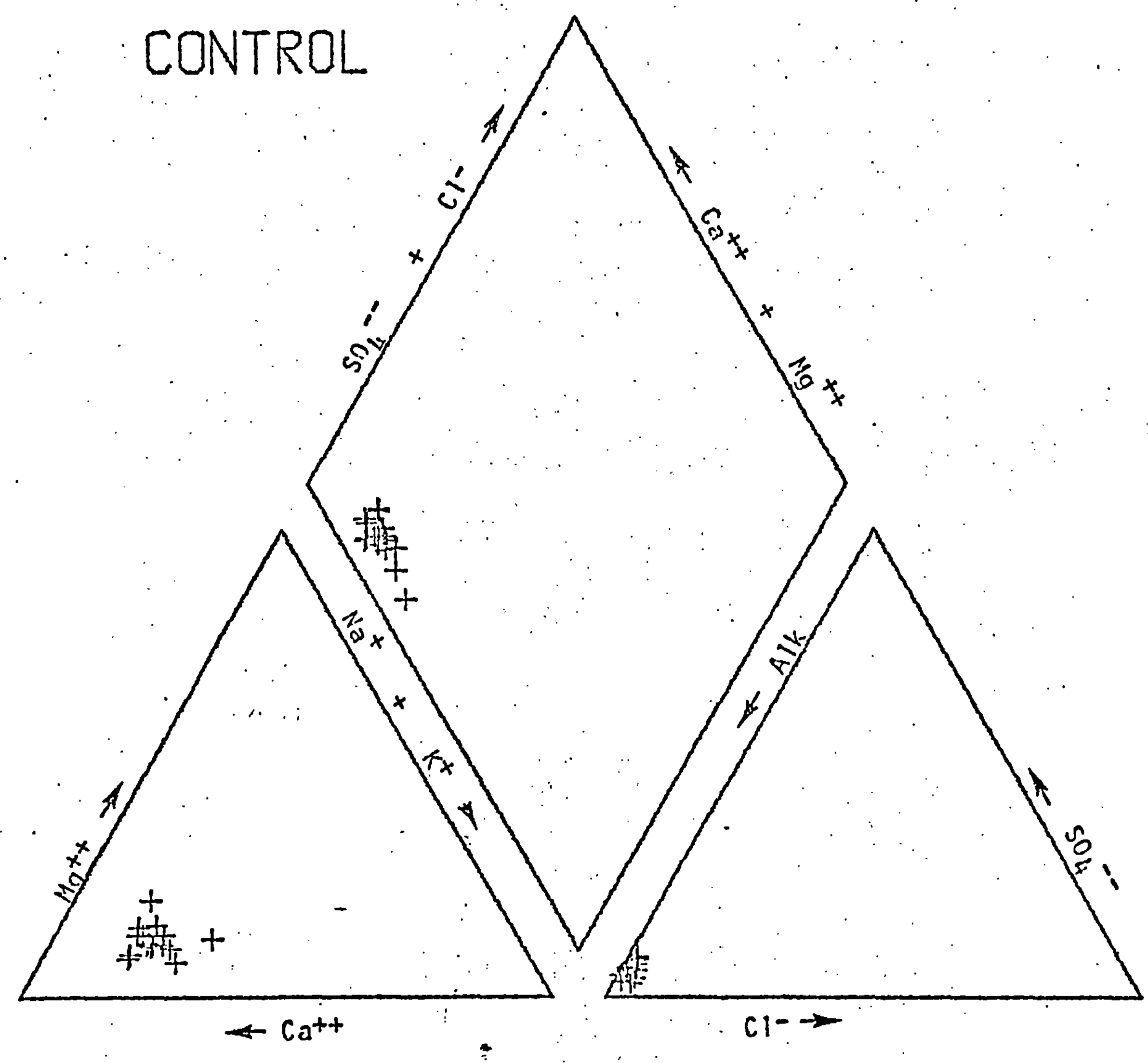

Figure 4a. Relative concentrations of important cations and anions within 15 "control" tributary sites, July 1982.

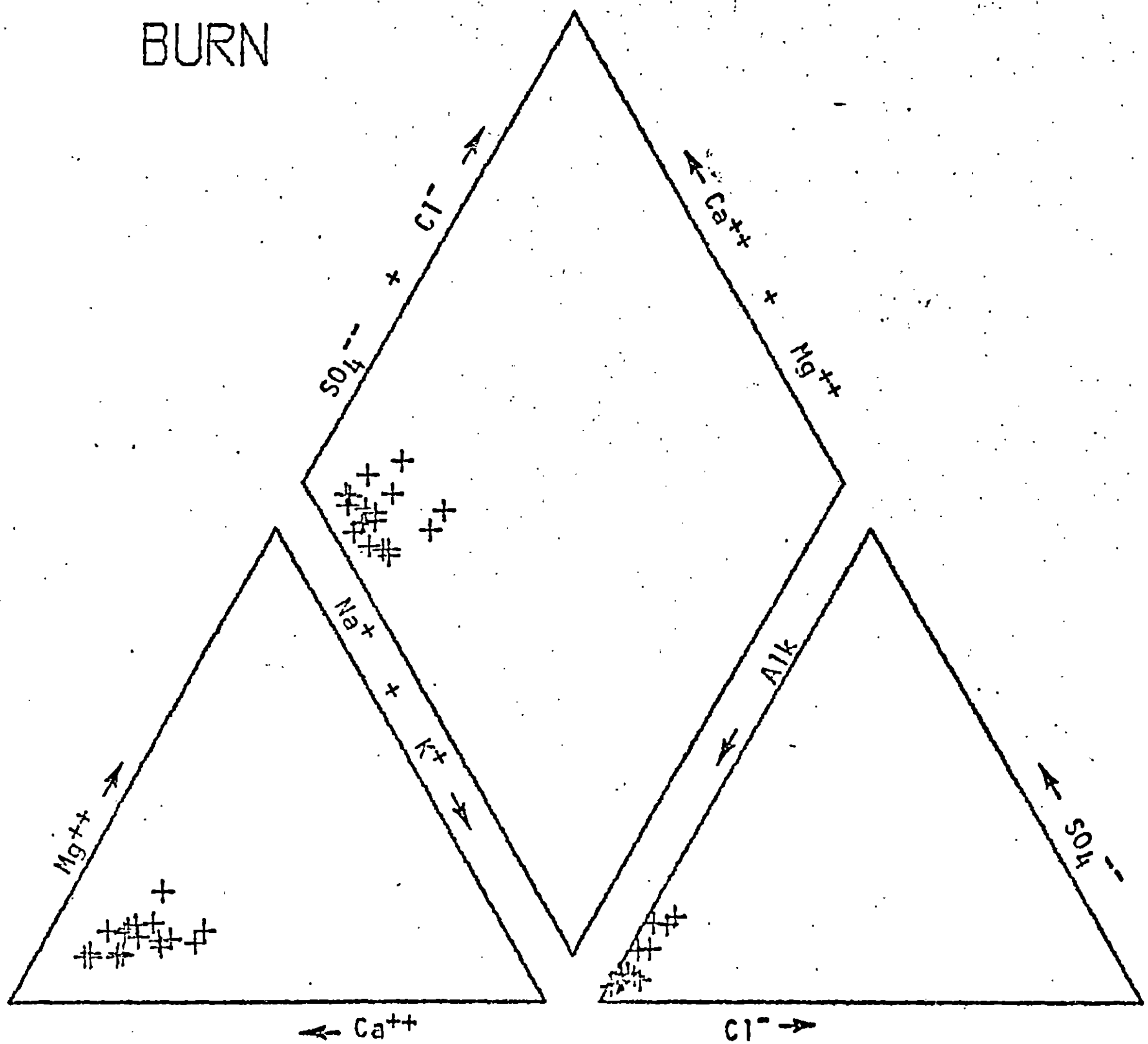

Figure 4b. Relative concentrations of important cations and anions within 13 "burn" tributary sites, July 1982.

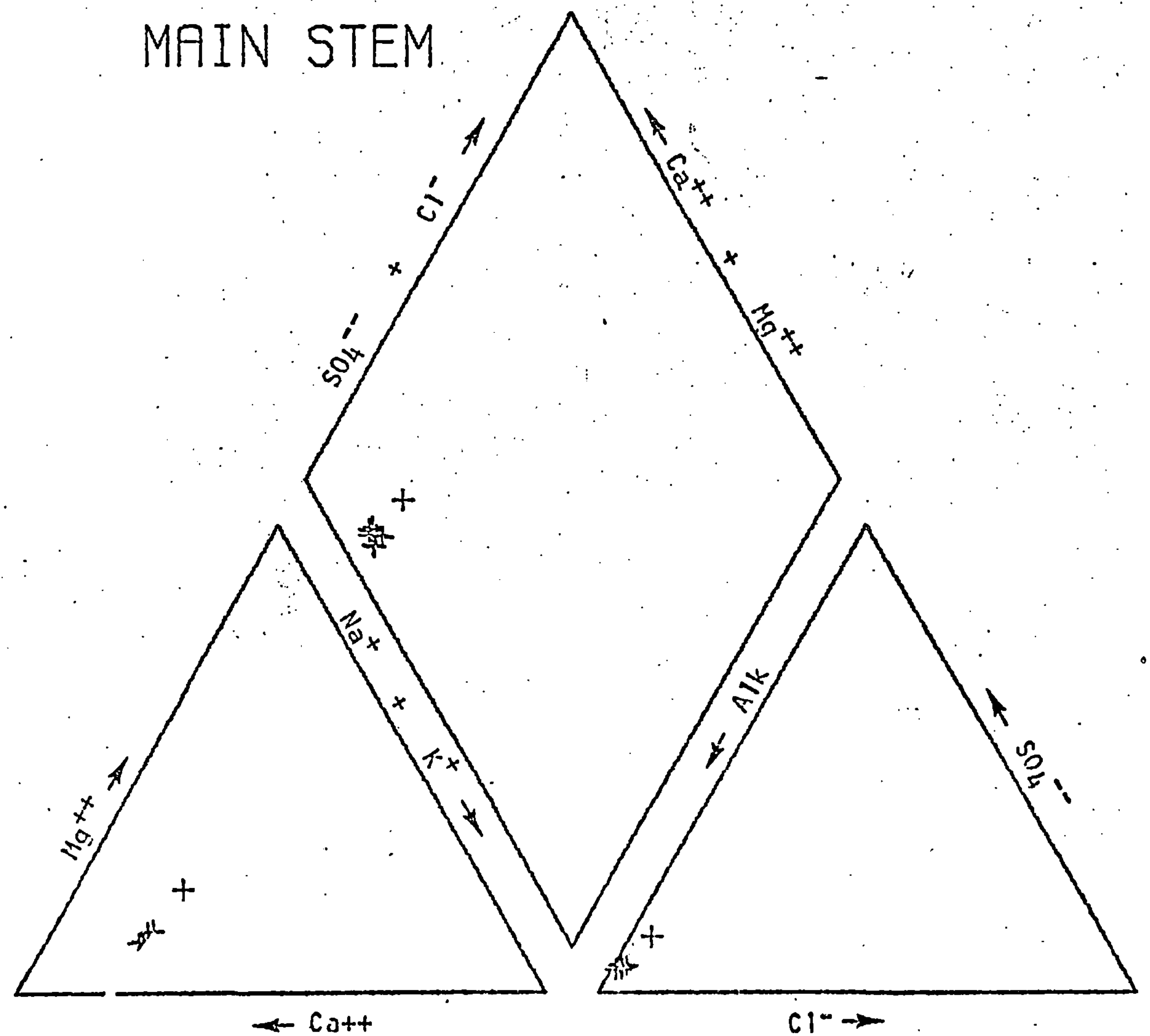

Figure 4c. Relative concentrations of important cations and anions within 12 mainstem sites on the Middle Fork of the Salmon River, July 1982.

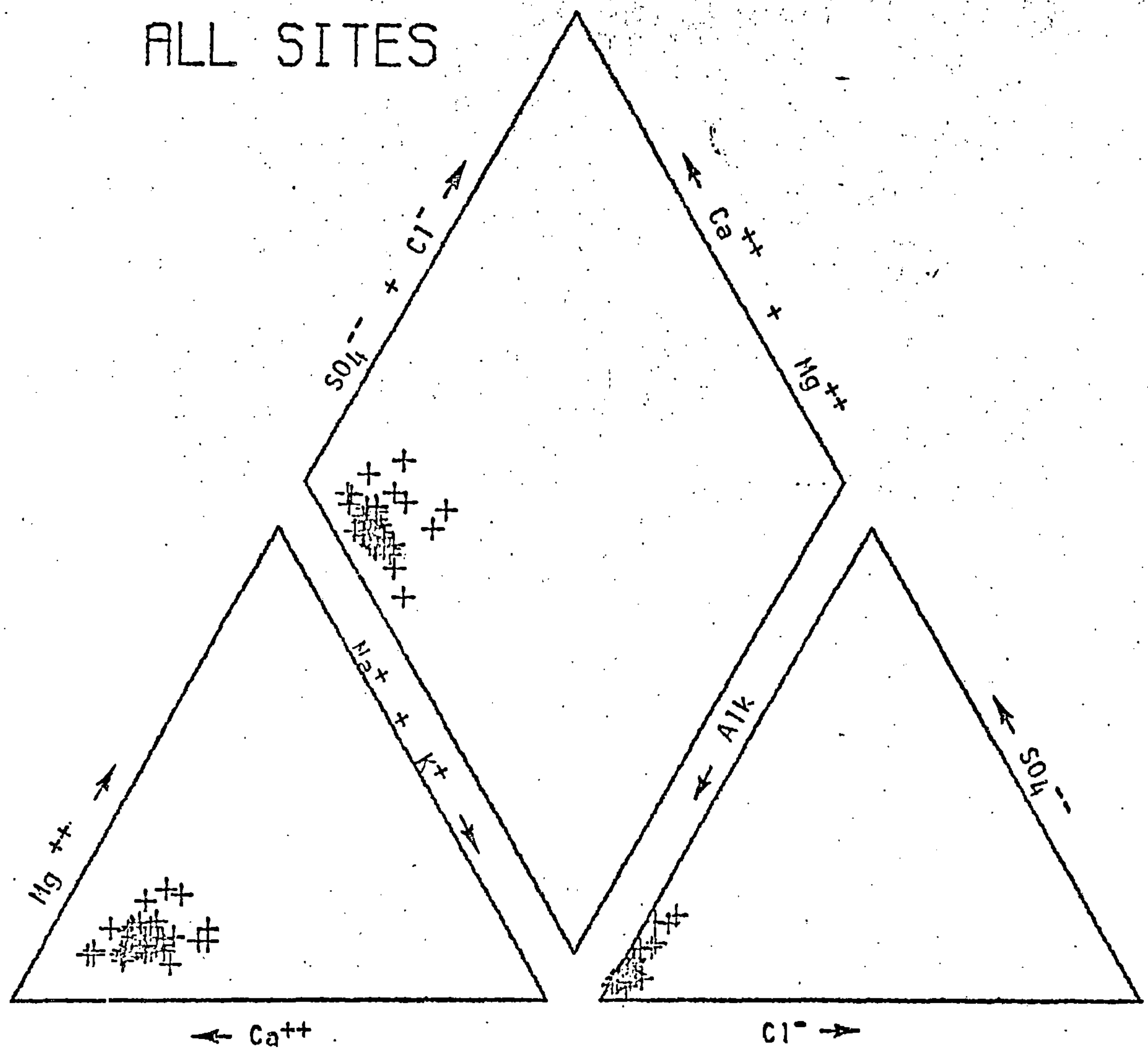

Figure 4d. Relative concentrations of important cations and anions for all tributary and mainstem sites combined, July, 1982.

(Dixon and Brown 1979). These analyses employ concentrations of all ions, conductivity, order and link number as variables. Factor analyses were performed on burn and control sites, respectively, and on all sites together. In the analysis for control sites, alkalinity was removed to avoid a singular matrix. All results derived three factors for which eigenvalues exceeded 1.0. These factors are composed as follows:

Factor 1: 4 to 7 variables, including cations, conductivity and one anion.

Factor 2: 1 to 5 variables, including phosphate, nitrate and 2 anions.

Factor 3: 2 variables, order and link number.

For each ion measured in this study, ion concentration was regressed onto stream order and onto log (stream link number) for control and burn sites. For each ion, slopes obtained from control were then compared to and burn regressions. None of the paired slopes were significantly different (t-test for differences between slopes, Sokal and Rohlf 1980).

Analyses of covariance followed the regression slope comparisons. Regardless of whether the analyses used stream order or log (stream link number) as the covariate, results obtained were identical (Table 8). This is not surprising as stream order and log (stream link number) are so highly correlated ($r = 0.98$). For each ion except potassium, sulphate and phosphate, the effect of stream order or log (stream link number) was statistically significant at $p \leq 0.05$. However, the main effect, that of control or burn, was significant only for fluoride and phosphate. It is evident (see Table 6) that fluoride concentrations are

Table 8. Results from analyses of covariance. An asterisk indicates an effect significant at $p \leq 0.05$; no entry indicates no significant effect.

ION	Analysis involving concentration		Analyses involving yield			
	Main Effect Type	Covariate Order or Log (Link)	Main Effect Type	Covariate Order	Main Effect Type	Covariate Log (Link)
Ca		*	*		*	
Mg		*				
Na		*		*		
K				*		*
Alk		*	*	*	*	*
SO_4						
Cl		*	*		*	
F	*	*				
PO_4^{3-}	*		*		*	
NO_3^-		*	p = .055		p = 0.57	

less and phosphate is in greater concentrations at burn sites than at control sites.

Similar analyses to those described above have been performed with ion yields (mass/km^2·day) from the tributary streams. Data used in these analyses are from those sites marked with an asterisk in Table 4. For all ions except fluoride, mean yield from burn sites exceeded those from control locations (Table 9). Mean fluoride yield was greater in control sites.

When Pearson product-moment correlations were performed on stream size measures and ion yield, only potassium yield correlated highly ($p \leq 0.05$) with all four stream-size measures (Table 10). However, stream order and log (stream link number) were also significantly correlated with sodium yield. No ion yields were significantly correlated with conductivity.

Regressions of ion yield versus stream order and versus log (stream link number) were performed on burn and control sites. Analyses of paired regression slopes for each ion (burn vs. control) indicate no statistically different causal relationships between ion yield and burn history. An analysis of covariance on these data, using site status (burn vs. control) as the main effect and either stream or log (stream link number) as the covariate, was performed. Results indicate burning significantly increased ion yields for calcium, alkalinity, chloride and phosphate (Table 11). The effect of burning on nitrate yield was not quite significant ($p \simeq 0.056$) with either log (stream link number) or stream order. Both covariates have a significant effect on potassium yield and alkalinity; stream order alone signficantly influences sodium yield.

Table 9. Average ion yields ± standard deviation found at control and burn sites, and at control plus burn sites combined. The sites involved are indicated by asterisks in Table 2. Units are $mg/km^2 \cdot day$ for phosphate and nitrate, and $meq/km^2 \cdot day$ for all other ions.

ION	CONTROL	BURN	CONTROL PLUS BURN
Ca^{2+}	0.4584 ± 0.2219	0.8023 ± 0.2792	0.6147 ± 0.2968
Mg^{2+}	0.0784 ± 0.0478	0.1316 ± 0.0650	0.1026 ± 0.0605
Na^{+}	0.1100 ± 0.0622	0.2013 ± 0.1165	0.1515 ± 0.0982
K^{+}	0.0152 ± 0.0076	0.0182 ± 0.0071	0.0165 ± 0.0072
Alkalinity	0.6149 ± 0.3062	1.0880 ± 0.4141	0.8300 ± 0.4201
SO_4^{2-}	0.0383 ± 0.0257	0.0600 ± 0.0260	0.0482 ± 0.0270
Cl^{-}	0.0070 ± 0.0051	0.0168 ± 0.0074	0.0115 ± 0.0078
F^{-}	0.0153 ± 0.0099	0.0074 ± 0.0037	0.0117 ± 0.0085
PO_4^{3-}	0.0063 ± 0.0042	0.0627 ± 0.0459	0.0319 ± 0.0415
NO_3^{-}	0.1277 ± 0.1777	0.4749 ± 0.3061	0.2855 ± 0.2935

Table 10. Summary of the Pearson product-moment correlation matrix for ion yield. Sites which provided data are indicated by an asterisk (*) in Table 2. A "significant correlation" is one which is significant at $p \leq 0.05$. For each combination in the table the data are (Number of significant correlations)/(Total number of possible correlations). Also indicated are the variables for which the correlations were not significant (Cond = Conductivity; Alk = Alkalinity; S = Sulfate; P = Phosphate; N = Nitrate; x·yz means variable x was not significantly correlated with y or z). For selected cases the value of the correlation coefficient is enclosed in parentheses. Neg indicates significant correlation coefficient)s) in those cases where a signed value is not provided.

	Area of Drainage Basin	Volume Discharge	Order	Link	Log (link)	Cations	Anions	PO_4^{3-} plus NO_3^-	Conductivity
Area of Drainage Basin	-	1/1 (.93)	1/1 (.65)	1/1 (.90)	1/1 (.76)	1/4 Ca,Mg,Na	0/4 Alk,S,Cl,F	0/2 P,N	1/1 (-.65)
Volume Discharge	1/1 (.93)	-	1/1 (.58)	1/1 (.73)	1/1 (.69)	1/4 Ca,Mg,Na	0/4 Alk,S,Cl,F	0/2 P,N	1/1 (-.64)
Order	1/1 (.65)	1/1 (.58)	-	1/1 (.76)	1/1 (.94)	2/4 Ca,Mg	0/4 Alk,S,Cl,F	0/2 P,N	0/1 Cond.
Link	1/1 (.90)	1/1 (.73)	1/1 (.76)	-	1/1 (.82)	1/4 Ca,Mg,Na	0/4 Alk,S,Cl,F	0/2 P,N	0/1 Cond.
Log (link)	1/1 (.76)	1/1 (.69)	1/1 (.94)	1/1 (.82)	-	2/4 Ca,Mg	2/4 Cl,F	0/2 P,N	0/1 Cond.
Cations	1/4 Ca,Mg,Na	1/4 Ca,Mg,Na	2/4 Ca,Mg	1/4 Ca,Mg,Na	2/4 Ca,Mg	6/6	12/16 F·all	6/8 N·MgK	0/4 Ca,Mg,Na,K
Anions	0/4 Alk,S,Cl,F	0/4 Alk,S,Cl,F	0/4 Alk,S,Cl,F	0/4 Alk,S,Cl,F	2/4 Cl,F	12/16 F·all	3/6 F·Alk,S,Cl	5/8 F·all,S·N	0/4 Alk,S,Cl,F
PO_4^{3-}	0/1 P	0/1 P	0/1 P	0/1 P	0/1 P	4/4	3/4 F	1/1 (.64)	0/1 P
NO_3^-	0/1 N	0/1 N	0/1 N	0/1 N	0/1 N	2/4 Mg,K	2/4 S,F	1/1 (.64)	0/1 N
Conductivity	1/1 (-.65)	1/1 (-.64)	0/1 Cond.	0/1 Cond.	0/1 Cond.	0/4 Ca,Mg,Na,K	0/4 Alk,S,Cl,F	0/2 P,N	-

Table 11. Summary of information found in six studies on the effect of burning or cutting on ion concentration and ion yield (mass/area·time).

Author	Parameter Measured	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Alk	SO_4^{2-}	Cl^{-}	F^{-}	PO_4^{2-}	NO_3^{-}	Time since disturbance
Johnson and Needham (1966)	concentration	inconclusive	inconclusive	inconclusive	- -	inconclusive	- -	- -	- -	- -	- -	2 wks. to 2 yrs.
Likens et al. (1970)*	concentration	+ *	+ *	+ *	+ *	N D *	N D *	+ *	- -	- -	+ *	1 yr. to 2 yrs.
	yield	+ *	+ *	+ *	+ *	N D *	N D *	+ *	- -	- -	+ *	
McColl and Grigall (1975)***	concentration	- -	- -	- -	- -	- -	- -	- -	- -	N D**	- -	
Wright (1976)****	concentration	N D	N D	N D	+	- -	- -	- -	- -	N D**	- -	Little Sioux Wildfire 1 yr. to 3 yrs.
McColl and Grigal (1977)***	concentration	N D	N D	- -	+	- -	- -	- -	- -	N D**	- -	
Schindler et al. (1980)	concentration	- -	- -	- -	+	- -	- -	- -	- -	+	+	1 yr. to 2 yrs.
	yield	- -	- -	- -		- -	- -	- -	- -	+	+	
Tiedemann et al. (1978)	concentration	N D	N D	N D	N D	N D at 3 yrs.	- -	- -	- -	+	+	
	yield****	+	+	+	- -	- -	- -	- -	- -	+	+	
This study	concentration	N D	N D	N D	N D	N D	N D	N D	+	+	N D	3 yr.
	yield	+	N D	N D	N D	+	N D	+	N D	+	+(?)	

Key:
- - - = no information
N D = no difference
\+ = value greater in burn streams

* Deforestation rather than burning
** X concentration was higher for two years following the burn, but the difference between burn and control was not statistically significant.
*** All these papers discuss data from the same burn
**** Different flow regimes in different years

Chemical and physical characteristics of nutrient ions can be useful for explaining observed differences in ion concentrations in streams. Data evaluated in different studies (Table 11) indicate cation concentrations are often significantly higher in burned streams. Lewis (1974) found solubility of divalent cations to dramatically increase following a burn; further, that monovalent cation solubility increases, but to a lesser extent. Anions are less soluble, overall, than cations. These trends are consistent with observations made during this study. One reason for this trend may be that Ca^{2+} and other cations are not as rapidly redistributed within plants. Therefore cations are more readily lost from the terrestrial ecosystem and increased concentrations are observed in stream ecosystems.

The explanation for increased nitrogen in some studies is more complex. In an unburned ecosystem, the primary mechanism of N retention is by maintaining only a small amount of the nutrient in an inorganic form (Henderson, et al. 1978). Thus, leaching is greatly reduced. Disruption of this balance by fire can result in a large nitrogen loss to stream ecosystems. Soil pH also influences the nitrogen amount available for transport across the terrestrial/aquatic interface. Increased acidity stimulates the activity of nitrogen-fixing bacteria and general microbial activity (Tiedemann et al. 1978, Likens et al. 1970). In an ecosystem deforested by fire, NO_3^- will be flushed into the streams. Inconsistancies in these patterns of nitrogen concentrations between burned and unburned streams may also be a function of the amount of nitrogen lost due to volatilization during the fire.

Trends observed for phosphate concentrations in burned streams are

more difficult to explain. Higher phosphate concentrations may stem from decreased plant uptake as a result of increased structural vulnerability of plant tissue to microbial activity. The effects of fire on phosphate needs to be more thoroughly investigated.

<u>Stream Substrate Permeability</u>

Stream substrate permeability is positively and significantly correlated with stream discharge ($r = 0.454$; $\alpha = 0.01$). However, there is no discernable difference between control and burn streams with respect to potential siltation and reduced permeability (Fig. 5). These results support those of a separate study on Rapid River, a tributary to the Middle Fork (Mitchell, C., Pers. Comm.; cf., Fig. 1) during the same year (summer, 1982). It appears storm events have a dramatic influence on stored substrate material. In Rapid River, as was the case on Little Loon Creek, scouring has shifted the bottom substrate considerably and washed out much of the fine sediments otherwise deposited within the streambeds.

<u>Stored and Transported Organic Material</u>

Core sample analyses provide measures of fine inorganic sediments (silts, sand, gravel) and deposited organic matter. Standing crop means (Table 12) are presented as ml sediment/20 cm^2. Two-way analyses of variance on square-root transformed percentage data indicates that, as would be expected, there are more organic sediments in depositional zones across all streams ($\alpha = 0.003$). Another strong, expected, difference is the much higher percentage of organic material in depositional zones ($\alpha = 0.018$) than in erosional zones.

The total quantity of inorganic fine sediments did not differ

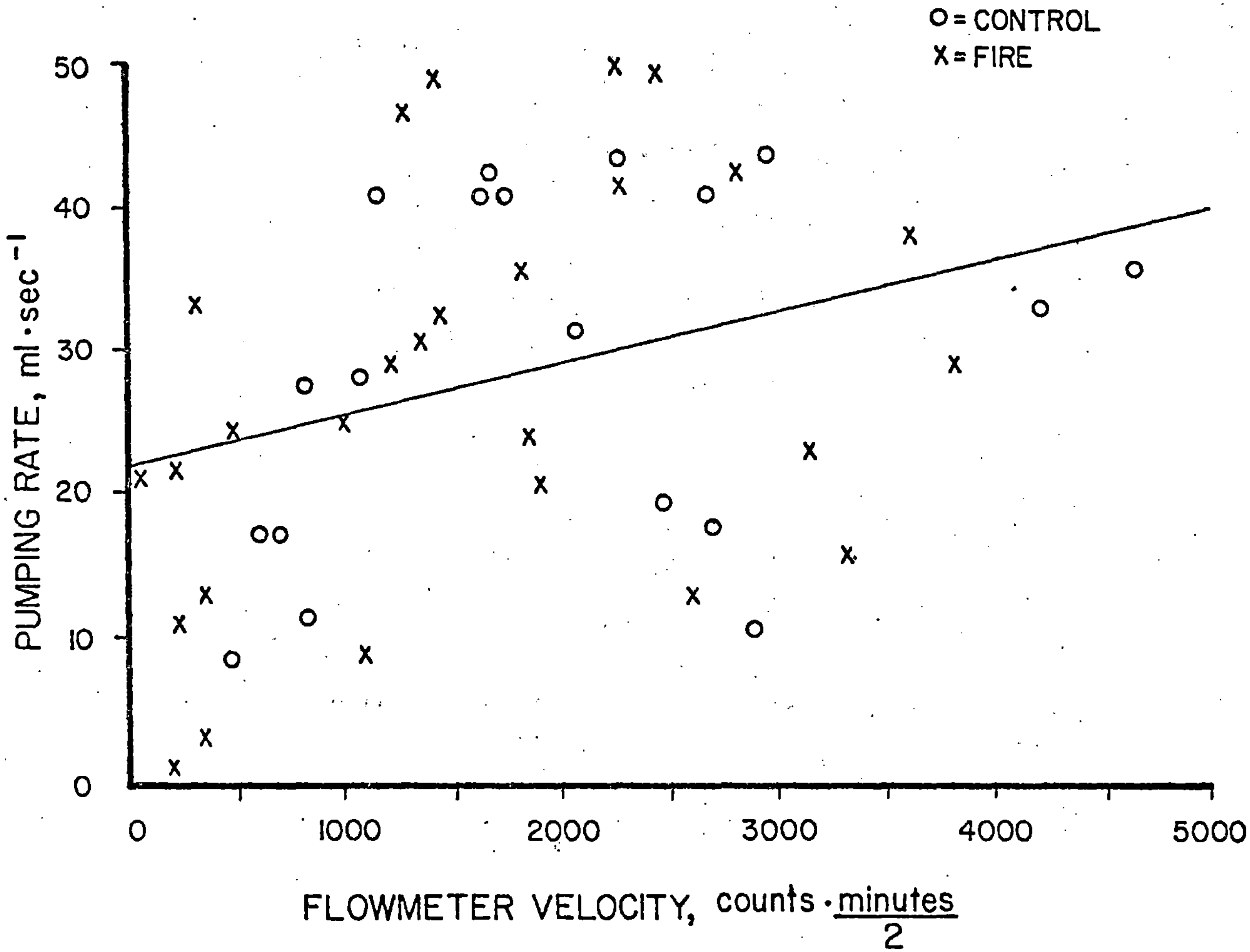

Figure 5. Rate of inflow into standpipe corer in gravel substrates as a function of stream velocity. Linear regression, r=0.90; Loglinear regression, r=0.98.

Table 12. Stored benthic organic plus inorganic sediments. Tabled are means and standard errors (in parentheses).

SITE	HABITAT	N	TOTAL ORGANIC	TOTAL INORGANIC			% ORGANIC
				SAND	GRAVEL	TOTAL	
Teapot Ck	Depo*	8	87.50 (31.96)	502.14 (202.13)	12.57 (5.36)	450.38 (184.74)	28.09 (7.92)
Charcoal Ck	Depo*	8	91.25 (44.43)	220.62 (60.87)	78.75 (26.74)	299.38 (48.46)	19.90 (5.52)
Pungo Ck	Depo	4	6.75 (1.97)	930.00 (158.48)	65.00 (55.45)	995.00 (189.27)	0.66 (0.17)
	Eros	4	7.75 (4.66)	308.75 (149.34)	28.75 (9.66)	337.50 (144.36)	1.85 (0.70)
Little Ck	Depo	4	225.25 (100.89)	233.75 (91.14)	33.00 (29.08)	266.75 (117.25)	48.56 (17.19)
	Eros	4	77.75 (57.55)	157.00 (59.33)	31.00 (16.44)	188.00 (63.83)	23.24 (9.34)
White Ck	Depo	4	176.25 (104.79)	530.00 (195.33)	23.75 (12.31)	553.75 (196.61)	30.13 (19.68)
	Eros	4	36.25 (8.00)	1112.50 (285.64)	360.00 (179.86)	1497.50 (338.76)	3.25 (1.25)
E Fk Indian Ck	Depo	4	25.5 (8.33)	418.75 (181.15)	35.25 (16.74)	454.00 (172.06)	5.75 (1.08)
	Eros	4	8.38 (2.91)	381.25 (70.72)	166.00 (50.61)	547.25 (93.24)	1.58 (0.58)
W Fk Little Loon Ck	Depo	4	18.00 (3.85)	796.25 (445.74)	10.00 (10.00)	806.25 (443.63)	5.73 (3.69)
	Eros	4	3.75 (2.39)	160.00 (54.20)	47.50 (31.19)	207.50 (75.40)	1.14 (0.76)
Indian Ck	Depo	4	23.75 (6.25)	666.25 (101.02)	101.00 (40.01)	767.25 (104.61)	2.97 (0.71)
	Eros	4	4.76 (2.38)	711.25 (242.52)	253.75 (166.78)	965.00 (287.47)	1.42 (0.95)
E Fk Little Loon Ck	Depo	4	0.50 (0.29)	1152.50 (419.66)	10.00 (10.00)	1162.50 (414.64)	0.06 (0.04)
	Eros	4	0.75 (0.75)	381.25 (137.09)	98.75 (65.33)	480.00 (147.48)	1.19 (1.19)
Marble Ck	Depo	4	3.00 (1.15)	1243.75 (429.26)	6.00 (3.11)	1249.50 (427.68)	0.71 (0.52)
	Eros	4	0.75 (0.25)	631.25 (110.57)	159.50 (36.86	790.75 (92.85)	0.10 (0.04)
Little Loon Ck, Mouth	Depo	4	0.75 (0.25)	1265.00 (474.58)	36.25 (19.30	1301.25 (470.28)	0.11 (0.06)
	Eros	4	2.00 (1.00)	647.50 (137.92)	58.75 (15.05)	706.25 (127.40)	0.37 (0.24)

* all cascade pools

between depositional and erosional zones across all streams. This result follows upon examining the large amount of sand and silt (Table 12) common to both substrate types and the much smaller component of gravel in either substrate type.

In no component of total inorganic sediments, total organic standing crop, or in percentage organic component of the deposited sediments are there statistically significant differences between burn and control stream sites. However, Pungo Creek, a control stream, individually had much less organic matter and a lower percentage organic material than did its contrast, Little Creek.

Visual examination of the coarse particulate organic matter (CPOM) associated with the collected invertebrates (Table 13) shows charcoal to be present only in burn sites in both erosional and depositional zones. In depositional zones alone, there is a larger CPOM standing crop in all control sites except within Teapot and Charcoal Creeks; this reversal can be attributed to a large quantity of deadfall and live foliage along Charcoal Creek.

Phytopigments (chlorophyll-a, phaeophytins) are presented in Table 14. There are large differences in amount of chlorophyll-a m^2 between burn and control streams. A comparison of chlorophyll-a to organic biomass would indicate, roughly, how much stored benthic organic material derives from primary producers. In this as well, there are substantial differences among control and burned streams. This corroborates observations on extant conditions in burn and control tributaries during the first post-fire year (Minshall, et al. 1981). At that time, a marked increase in benthic chlorophyll was observed in burn tributaries. That trend has continued, largely as a function of reduced

Table 13. Coarse particulate organic matter amount (g AFDM/m^2) and composition (%) associated with macroinvertebrate samples. Composition determined by visual examination, July 1982.

Station		Amount	COMPOSITION						
			Moss	Decid. Leaves	Conif. Needles	Sticks	Bark	Amorph. Detrit.	Charc.
Erosional									
Teapot Ck	(C)	25.1	0	5	5	20	10	60	0
Charcoal Ck	(B)	15.2	15	0	0	20	5	25	35
Pungo Ck	(C)	1.7	0	0	0	10	0	90	0
Little Ck	(B)	22.3	5	0	0	55	10	15	15
White Ck	(C)	8.7	0	0	45	45	0	40	0
E Fk Indian Ck	(C)	4.0	0	0	25	15	10	50	0
W Fk Little Loon	(B)	17.9	0	0	0	60	5	25	10
Indian Ck	(C)	32.3	0	0	0	50	13	35	2
E Fk Little Loon	(B)	3.4	5	0	0	20	0	75	5
Marble Ck	(C)	9.3	0	0	0	25	25	50	0
Little Loon Ck	(B)	1.2	0	0	0	20	0	80	2
Depositional									
Teapot Ck	(C)	14.8	5	5	5	5	10	70	0
Charcoal Ck	(B)	35.9	3	0	0	20	0	27	48
Pungo Ck	(C)	16.4	0	5	0	35	10	50	0
Little Ck	(B)	6.6	0	11	0	20	0	60	9
White Ck	(C)	44.6	2	17	23	30	10	15	0
E Fk Indian	(C)	13.9	0	0	0	20	10	70	0
W Fk Little Loon	(B)	4.6	0	0	0	20	5	60	15
Indian Ck	(C)	29.8	0	0	0	30	10	60	0
E Fk Little Loon	(B)	1.8	0	0	0	55	5	40	3
Marble Ck	(C)	11.1	0	0	5	20	5	70	0
Little Loon Ck	(B)	1.0	0	0	0	0	0	100	0

Table 14. Chlorophyll-a, phaeophytin, ash-free dry mass (AFDM) and the ratio of chlorophyll-a to organic material in the benthos of Middle Fork of the Salmon burn and control tributaries. All values in mg/m^2 unless otherwise noted.

Stream	Status*	Chla $\bar{X} \pm$ S.D.	Phaeophytius $\bar{X} \pm$ S.D.	AFDM, g/m^2 $\bar{X} \pm$ S.D.	Chla/Biomass, mg/g, $\bar{X} \pm$ S.D.
Teapot Ck	C	10.36 ± 9.95	39.70 ± 36.18	5.24 ± 3.02	1.77 ± 0.91
Charcoal Ck	B	178.55 ± 75.47	115.57 ± 51.72	44.82 ± 22.84	4.23 ± 0.79
Pungo Ck	C	1.43 ± 0.86	4.11 ± 1.74	2.53 ± 0.96	0.59 ± 0.31
Little Ck	B	15.98 ± 8.35	46.71 ± 28.59	13.11 ± 4.89	1.18 ± 0.45
White Ck	C	4.36 ± 1.47	2.07 ± 1.64	4.77 ± 1.85	1.10 ± 0.60
East Fk Indian Ck	C	3.25 ± 2.18	11.84 ± 7.18	3.71 ± 1.31	0.80 ± 0.34
West Fk Indian Ck	B	3.69 ± 4.18	16.01 ± 17.41	5.01 ± 3.65	0.58 ± 0.30
Indian Ck	C	0.28 ± 0.14	1.33 ± 1.47	2.85 ± 0.68	0.11 ± 0.03
East Fk Little Loon Ck	B	1.97 ± 0.53	5.93 ± 1.32	4.73 ± 1.24	0.43 ± 0.12
Marble Ck	C	0.52 ± 0.10	1.53 ± 0.58	2.06 ± 0.58	0.28 ± 0.11
Little Loon Ck	B	33.27 ± 22.55	80.06 ± 72.93	12.53 ± 12.01	3.11 ± 1.74

*
B=Burn
C=Control

canopy cover.

There was a significantly greater ($\alpha = 0.001$) concentration of particulate organic material transported in burn than in control streams (Table 15) in 1982. Our single sample period makes it impossible to extrapolate these differences in transported organic matter to any yearly trends. However, the unstable nature of the slopes in burned watersheds may contribute to the observed increase in transported material. There are no statistically apparent differences in either dissolved organic carbon concentration, nor in percentage organic composition among control and burn streams.

Benthic Macroinvertebrates

All collected benthic macroinvertebrates were identified to the lowest practicable taxon, counted and weighed. The data have been examined from several perspectives, including taxonomic composition and functional group (= trophic status) composition. Further analyses include calculating species richness, equitability and diversity for erosional and depositional zones in all streams.

Mean abundances (Nos/m^2) of collected invertebrates are listed by taxon and functional group in Tables 16 and 17. Mean invertebrate biomasses (mg dry mass/m^2) are listed in Tables 18 and 19. Overall, similar taxa were distributed over erosional and depositional zones in burn and control streams.

Differences become apparent among burn and control streams in mean number of collected invertebrates (Table 20). Except for the greater number of invertebrates collected per square meter in Charcoal Creek and in Little Loon Creek, there are no significant differences in

Table 15. Transported material in Middle Fork of the Salmon tributaries. Dissolved organic carbon (DOC), particulate organic material (POM; ≥ 52 μm), and percent organic content of total transported suspended solids.

	Status*	DOC, mgC/l	POM, mgAFDM/l	Percent Organic
Teapot Ck	C	1.16	0.26	26.0
Charcoal Ck	B	1.26	0.97	37.7
Pungo Ck	C	0.81	0.44	24.9
Little Ck	B	2.38	0.81	31.4
White Ck	C	1.52	0.40	38.7
East Fk Indian Ck	C	1.17, 1.93, 1.10, 1.09	0.26, 0.37, 0.42, 0.28	27.3, 33.8, 35.3, 27.2
West Fk Little Loon	B	0.82	1.01	53.9
Indian Ck	C	1.22, 1.06, 0.91, 1.28	0.46, 0.62, 0.46, 0.50	26.5, 31.3, 30.6, 26.9
East Fk Little Loon	B	1.20	2.47	26.6
Marble Ck	C	1.32	0.35	19.3
Little Loon Ck	B	1.29, 1.36, 1.60, 1.29	1.43, 1.25, 1.76, 1.13	22.0, 19.9, 21.8, 26.8

* C = control

B = burn

Table 5. Abundances (nos/m^2) of benthic macroinvertebrates collected from erosional areas in summer 1982 (C=control, B=burn site).

	Tenpot Creek (C)		Charcoal Creek (B)		Fungo Creek (C)		Little Creek (B)		White Creek (C)	
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Scraper										
Baetis bicaudatus	245.7	111.4	78.3	56.5	78.3	71.3	280.8	305.6	2.7	5.4
Baetis tricaudatus			72.9	65.7	48.6	45.4			67.5	64.5
Cinygmula sp.	191.7	202.3			162.0	101.7	29.7	38.8	29.7	28.4
Epeorus deceptivus	8.1	10.8	10.8	8.2	164.7	85.2	78.3	61.3		
E. longimanus			13.5	10.4	27.0	25.7	27.0	6.3		
Ephemerella doddsi			8.7	5.4	21.6	36.4	2.7	5.4	2.7	5.4
E. flavilinea			13.5	5.4	24.3	28.4	156.6	71.4	18.9	30.9
E. spinifera										
E. tibialis					16.2	13.9			2.7	5.4
Glossosoma sp.									5.4	10.8
Heterelmis					18.9	18.5			105.3	69.1
Lara									2.7	3.2
Optioservus										
Narpus										
Neophylax sp.					2.7	5.4				
Neothremma sp.	37.8	51.1	5.4	6.3			5.4	5.4	2.7	5.4
Rhithrogena sp.					10.8	21.6				
Stenelmis					1.4	2.7			1.4	2.7
Total	483.3		203.1		576.5		580.5		241.7	
Shredder										
Limnephilus sp.										
Psychoglypha sp.										
Pteronarcys californica										
Tipula sp.					2.7	5.4				
Yoroperla brevis	29.7	13.6	10.8	15.2	2.7	5.4	16.2	13.9		
Zapada oregonensis	124.2	90.2			40.5	60.1				
Total	153.9		10.8		45.9		16.2		0	
Gatherer										
Ameletus cooki										
A. similor	5.4	10.8	17.5	1.0						
A. velox									5.4	10.8
Capniidae	2.7	5.4	8.1	10.4	8.1	5.4				
Dixa sp.	2.7	5.4								
Ephemerella grandis										
Heterelmis					18.9	18.5			1.4	2.7
Lara									2.7	3.2
Lepidostoma sp.	10.8	15.2								
Narpus										
Neothremma sp.										
Optioservus										
Paraleptophlebia sp.	24.3	30.9			2.7	5.4	2.7	5.4		
Rhyacophila acropedes	8.1	10.4	2.7	5.4	29.7	30.8			10.8	15.2
Stenelmis					1.4	2.7			1.4	2.7
Total	54.0		28.3		60.8		2.7		20.5	
Filterer										
Arctopsyche grandis										
Brachycentrus sp.										
Hydropsyche sp.										
Parapsyche elsis	18.9	16.2	8.1	10.4	5.4	6.3	2.7	5.4	10.8	15.2
Pisidium sp.										
Simulium sp.	5.4	6.3	27.0	35.9			27.0	35.9		
Total	24.3		35.1		5.4		29.7		10.8	
Miner										
Chironomidae	56.7	27.0	105.3	125.5	40.5	32.3	1093.5	323.4		
Lumbriculus sp.	2.7	5.4	2.7	5.4	5.4	10.8	13.5	20.4		
Tubificidae	24.3	22.3	64.8	108.3	43.8	49.1			2.7	5.4
Total	83.7		172.8		89.7		1107.0		2.7	
Predator										
Atherix variegata							2.7	5.4		
Calineuria sp.									5.4	62.6
Ceratopogonidae					2.7	5.4				
Chloroperlidae	5.4	10.8	2.7	5.4	27.0	18.7				
Claassenia sp.										
Dicronota sp.										
Dytiscidae										
Empididae										
Hesperoperla pacifica										
Hexatoma sp.										
Hydracarina					5.4	10.8				
Isogenoides sp.					2.7	5.4				
Isoperla sp.	10.8	15.2			8.1	16.2				
Megarcys sp.							2.7	5.4		
Muscidae										
Nematoda					2.7	5.4				
Perlodinae					8.1	16.2				
Perlesta sp.										
Rhyacophila sp. A										
R. angelita					8.1	10.4			2.7	5.4
R. hyalinata			5.4	6.3						
R. vaccua									2.7	5.4
R. vagrita			64.8	46.6			32.4	19.8		
R. verrula	10.8	15.2								
R. vepulsa					8.1	16.2				
Setvena bradleyi	5.4	10.8	18.9	16.2			18.9	18.5	21.6	36.4
Skwala sp.										
Turbellaria	148.5	41.7	270.0	229.8	27.0	32.4	99.9	51.7	21.6	30.0
Total	100.9		361.8		99.9		156.6		54.0	

	West Fork Little Loon (B)		East Fork Little Loon (B)		Indian Creek (C)		East Fork Indian Creek (C)		Marble Creek (C)		Little Loon Mouth (B)	
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Scraper												
Baetis bicaudatus	153.9	40.6	213.5	110.3	40.5	16.2	10.8	15.3	18.0	16.5	27.0	13.9
Baetis tricaudatus	5.4	6.3			40.5	18.5	35.1	43.5	32.4	15.2		
Cinygmula sp.					24.3	30.9	91.8	112.4	2.7	5.4		
Epeorus deceptivus	10.8	8.9	13.5	27.0	5.4	10.8			5.4	10.8		
E. longimanus	29.7	29.7	35.9	16.5	35.1	16.2			10.8	12.4		
Ephemerella doddsi					8.1	5.4	10.8	15.1				
E. flavilinea	24.3	10.4	8.1	10.4	2.7	5.4	29.7	28.4	5.4	6.3		
E. spinifera					2.7	5.4						
E. tibialis					18.9	10.4	10.8	8.9	16.2	13.9		
Glossosoma sp.												
Heterelmis	1.4	2.7					6.7	10.2			1.4	2.7
Lara												
Optioservus									4.1	5.2		
Narpus									1.4	2.7		
Neophylax sp.							5.4	6.3				
Neothremma sp.	2.7	5.4										
Rhithrogena sp.			2.7	5.4	16.2	13.9						
Stenelmis	1.4	2.7	1.4	3.2			1.4	2.7				
Total	228.2		277.5		194.4		202.5		96.4		28.4	
Shredder												
Limnephilus sp.					2.7	5.4						
Psychoglypha sp.			2.7	5.4								
Pteronarcys californica									2.7	5.4		
Tipula sp.					2.7	5.4			5.4	6.3		
Yoroperla brevis												
Zapada oregonensis							5.4	6.3				
Total	0		2.7		5.4		5.4		8.1		0	
Gatherer												
Ameletus cooki												
A. similor												
A. velox												
Capniidae												
Dixa sp.												
Ephemerella grandis												
Heterelmis	1.4	2.7					6.7	10.2			1.4	2.7
Lara												
Lepidostoma sp.									2.7	5.4		
Narpus									1.4	2.7		
Neothremma sp.												
Optioservus									4.1	5.2		
Paraleptophlebia sp.					2.7	5.7	2.7	5.4				
Rhyacophila acropedes					21.6	8.9	8.1	10.4				
Stenelmis	1.4	2.7	1.4	3.2			1.4	2.7				
Total	2.8		1.4		42.3		18.9		8.2		1.4	
Filterer												
Arctopsyche grandis					5.4	10.8						
Brachycentrus sp.			2.7	5.4	62.1	55.3			116.1	82.9	8.1	10.4
Hydropsyche sp.					8.1	10.4			32.4	30.9		
Parapsyche elsis							2.7	5.4				
Pisidium sp.					2.7	5.4						
Simulium sp.	113.4	98.4	5.4	10.8	8.1	16.2			8.1	10.4		
Total	113.4		8.1		86.4		2.7		156.6		8.1	
Miner												
Chironomidae	318.6	228.9	4166.6	1895.2	21.6	15.2	16.2	25.7	113.4	79.2	908.2	199.0
Lumbriculus sp.												
Tubificidae	5.4	10.8	16.2	20.7			137.7	261.0	2.7	5.4		
Total	324.0		4182.8		21.6		153.9		116.1		908.2	
Predator												
Atherix variegata	2.7	5.4	10.8	12.5					8.1	10.4		
Calineuria sp.					2.7	5.4	5.4	10.8			5.4	10.8
Ceratopogonidae									2.7	5.4		
Chloroperlidae	5.4	6.3			16.2	13.9	8.1	10.4	21.6	19.8	2.7	5.4
Claassenia sp.												
Dicronota sp.	5.4	10.8										
Dytiscidae												
Empididae	2.7	5.4			2.7	5.4						
Hesperoperla pacifica					2.7	5.4			8.1	10.4		
Hexatoma sp.												
Hydracarina									2.7	5.4		
Isogenoides sp.												
Isoperla sp.					2.7	5.4	13.5	10.4				
Megarcys sp.												
Muscidae	2.7	5.4										
Nematoda												
Perlodinae												
Perlesta sp.					5.4	10.0			5.4	10.8		
Rhyacophila sp. A			2.7	5.8								
R. angelita												
R. hyalinata												
R. vaccua			2.5	5.8			2.7	5.4				
R. vagrita	72.9	53.1	5.4	6.3								
R. verrula												
R. vepulsa							2.7	5.4				
Setvena bradleyi			5.4	6.3	2.7	5.4						
Skwala sp.												
Turbellaria							45.9	40.8	5.4	10.8		
Total	91.8		26.8		35.1		78.5		54.0		8.1	

Table 17 Abundance (nos/m²) of benthic macroinvertebrates collected from depositional areas in Summer 1982. (C=control, B=burn site)

	Teapot Creek (C) x̄	SD	Charcoal Creek (B) x̄	SD	Pungo Creek (C) x̄	SD	Little Creek (B) x̄	SD	White Creek (C) x̄	SD	West Fork Little Loon (B) x̄	SD	East Fork Little Loon (B) x̄	SD	Indian Creek (C) x̄	SD	East Fork Indian Creek (C) x̄	SD	Marble Creek (C) x̄	SD	Little Loon Mouth (B) x̄	SD
Scraper																						
Baetis bicaudatus			35.1	13.6					21.6	8.9	167.4	150.3	2.7	5.4			13.5	13.6	13.5	13.6	10.8	8.9
Baetis tricaudatus			48.6	22.5	115.4	84.8	83.7	60.1	13.5	10.4	2.7	5.4			64.8	115.7	32.4	23.3	2.7	5.4		
Cinygmula sp.	13.5	5.4	21.5	15.2	310.5	270.5	24.3	13.6	64.8	61.8	8.1	16.2			8.1	16.2	70.2	85.3				
Epeorus deceptivus					29.7	99.4	10.8	15.2			24.3	22.3					2.7	5.4				
E. longimanus			2.7	5.4	8.1	10.4					5.4	10.8					2.7	5.4				
Ephemerella doddsi					5.4	6.3											2.7	5.4				
E. flavilinea					10.8	8.9	2.7	5.4	2.7	5.4	5.4	6.3					2.7	5.4				
E. spinifera																						
E. tibialis					5.4	10.8			5.4	6.3	8.1	5.4			8.1	16.2	16.2	13.9				
Glossosoma sp.																						
Heterelmis					17.5	14.2			39.1	47.6							22.2	10.2				
Lara																						
Optioservus																						
Narpus									7.7	10.2												
Neophylax sp.					13.5	16.2			2.7	5.4												
Neothremma sp.	59.4	84.8	5.4	10.8											8.1	16.2			2.7	5.4		
Rhithrogena sp.																						
Stenelmis									14.5	14.2							2.7	3.1				
Zaitzevia																						
Total	72.9		113.3		514.3		121.5		172.0		221.4		2.7		89.1		168.0		18.9		10.8	
Shredder																						
Limnephilus sp.																			2.7	5.4		
Psychoglypha																						
Pteronarcys californica																						
Tipula sp.									2.7	5.4							2.7	5.4	2.7	5.4		
Yoroperla brevis	43.2	52.2					8.1	10.4									5.4	10.8				
Zapada oregonensis	29.7	13.6	2.7	5.4	29.7	29.7	2.7	5.4														
Total	72.9		2.7		29.7		10.8		2.7		0		0		0		8.1		5.4		0	
Gatherer																						
Ameletus cooki											10.8	0.0	2.7	5.4	13.5	16.2			2.7	5.4	13.5	13.6
A. similor	24.8	35.6	13.5	16.2	21.6	12.4			21.6	8.9	2.7	5.4					10.8	21.6				
A. velox			32.4	19.8	8.1	16.2	59.4	53.2			10.8	15.2	2.7	5.4	13.5	10.4						
Capniidae			16.2	13.9			2.7	5.4														
Dixa sp.							2.7	5.4														
Ephemerella grandis																	22.2	10.2				
Heterelmis					17.5	14.2			39.1	47.6												
Lara																						
Lepidostoma sp.							8.1	10.4	2.7	5.4												
Narpus									7.7	10.2												
Neothremma sp.							10.8	8.9														
Optioservus																						
Paraleptophlebia sp.	25.7	16.3			2.7	5.4									10.8	12.4						
Rhyacophila acropedes	2.7	5.4			2.7	5.4			2.7	5.4							2.7	3.1				
Stenelmis					14.5	14.2																
Zaitzevia																						
Total	53.2		67.1		67.1		83.7		73.8		24.3		5.4		37.8		35.7		2.7		13.5	
Filterer																						
Arctopsyche grandis	2.7	5.4																	2.7	5.4		
Brachycentrus sp.																						
Hydropsyche sp.															2.7	5.4	2.7	5.4				
Parapsyche elis					2.7	5.4																
Pisidium sp.																						
Simulium sp.			2.7	5.4			13.5	20.4			2.7	5.4										
Total	2.7		2.7		2.7		13.5		0		2.7		0		2.7		2.7		2.7		0	
Miner																						
Chironomidae	2.7	5.4			27.0	28.6	677.7	149.8	2.7	5.4	175.5	40.7	486.0	279.2	18.9	18.5	29.7	33.5	16.2	25.7	191.7	85.2
Lumbriculus sp.	56.7	56.1	5.4	10.8	5.4	10.8			43.2	72.1							132.3	123.2				
Tubificidae	13.5	20.4	321.3	267.2	224.1	179.3	62.1	91.8	8.1	10.4												
Total	72.9		326.7		256.5		739.8		54.0		175.5		486.0		18.9		162.0		16.2		191.7	
Predator																						
Atherix variegata											2.7	5.4			2.7	5.4	21.6	36.4				
Calineuria sp.			2.7	5.4																		
Ceratopogonidae											2.7	5.4			16.2	10.8	27.0	20.6	5.4	6.3		
Chloroperlidae	27.0	40.9			64.8	44.9			46.8	64.7					2.7	5.4						
Claassenia sp.											8.1	10.4										
Dicronota sp.																			2.7	5.4		
Dytiscidae																						
Empididae							2.7	5.4														
Hesperoperla pacifica																						
Hexatoma sp.																						
Hydracarina							10.8	8.9													2.7	5.4
Isoquenoidea sp.																						
Isoperla sp.					8.1	16.2											18.9	18.5				
Megarcys sp.																						
Muscidae											2.7	5.4										
Nematoda																						
Perlodinae							2.7	20.7														
Perlesta sp.																						
Rhyacophila angelita					2.7	5.4																
R. hyalinata																						
R. vaccua			2.7	5.4	10.8	15.2			2.7	5.4							2.7	5.4				
R. vagrita			24.3	23.9							29.7	10.4										
R. verrula							5.4	10.8														
R. vepulsa					8.1	10.4	29.7	13.6	13.5	20.4							10.8	15.2				
Setvena bradleyi	5.4	6.3	8.1	5.4	2.7	5.4	18.9	13.6	2.7	5.4							5.4	10.8				
Skwala sp.																						
Turbellaria	259.2	164.5	299.7	85.6	86.4	44.9	210.6	164.2	37.8	51.1							29.7	22.3				
Total	291.6		337.5		183.6		280.8		103.5		45.9		0		21.6		116.1		8.1		2.7	

Table 18 Biomass (mg dry wt/m^2) of benthic macroinvertebrates collected from erosional areas in Summer 1987. (C=control, B=burn site)

	Teapot Creek (C)		Charcoal Creek (B)		Pungo Creek (C)		Little Creek (B)		White Creek (C)		West Fork Little Loon (B)		East Fork Little Loon (B)		Indian Creek (C)		East Fork Indian Creek (C)		Marble Creek (C)		Little Loon Mouth (B)	
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Scraper																						
Baetis bicaudatus	59.4	31.3	5.4	6.5	14.4	9.7	84.2	20.5			55.8	27.0	71.3	20.1	30.2	38.9					2.2	4.3
Baetis tricaudatus			59.4	52.9	16.2	19.4			24.8	36.7					40.0	52.9	40.9	46.4	8.6	0		
Cinygmula sp.	94.0	110.2			65.9	58.3	36.7	41.0	14.0	13.0					6.5	5.4	28.1	33.5	3.2	6.5		
Epeorus deceptivus					24.8	18.4	21.6	17.3			3.2	3.2			1.1	2.2						
E. longimanus			24.8	39.2	4.3	4.3	51.8	47.5			52.9	65.9	6.5	5.4	34.6	34.6			3.2	5.4		
Ephemerella doddsi					281.9	454.7	76.7	153.4	8.6	16.2					129.6	102.6	119.9	168.5				
E. flavilinea			74.5	49.7	45.4	48.6	1113.5	506.5	36.7	59.4	82.1	76.7	27.0	32.4	9.7	20.5	46.4	58.3	5.4	8.6		
E. spinifera															74.5	149.0						
E. tibialis					5.4	7.6									18.4	24.8	1.1	2.2	4.3	3.2		
Glossosoma sp.									7.6	15.1												
Heterelmis					2.1	2.7			7.5	5.4							1.6	2.7				
Lara									1.1	2.7												
Optioservus																			0.5	1.6		
Narpus																						
Neophylax sp.					5.4	11.9											10.8	21.6				
Neothremma sp.	60.5	91.8	1.08	3.24			22.7	29.2	11.9	23.8												
Rhithrogena sp.															41.0	20.5						
Stenelmis									0.5	1.6	0.5	1.8					2.7	5.4				
Total	213.9		165.2		465.8		1407.2		112.7		194.5		104.8		385.6		210.6		25.2		2.2	
Shredder																						
Limnephilus sp.															235.4	470.9						
Psychoglypha sp.													30.0	60.0								
Pteronarcys californica																			52.9	109.0		
Tipula sp.																			2.2	4.3		
Yoroperla brevis	17.3	15.1	18.4	24.8	1.1	3.2	11.9	13.0														
Zapada oregonensis	34.6	30.2			3.2	6.5																
Total	51.9		18.4		4.3		11.9		0		0		30.0		235.4		0		55.1		0	
Gatherer																						
Ameletus cooki																						
A. similor	2.2	4.3	5.4	10.8																		
A. velox									4.3	8.6												
Capniidae	1.1	3.2			1.1	2.2																
Dixa sp.																						
Ephemerella grandis																						
Heterelmis					2.1	2.7			7.5	5.4							1.6	2.7				
Lara									1.1	2.7												
Lepidostoma sp.																						
Narpus																						
Neothremma sp.																						
Optioservus																			0.5	1.6		
Paraleptophlebia sp.	2.2	4.3																				
Rhyacophila acropedes	27.0	44.3			1530.4	2976.5	61.6	124.2	4.8	4.8					7.6	5.4	63.7	73.4				
Stenelmis									0.5	1.6	0.5	1.0					2.7	5.4				
Total	32.5		5.4		1533.6		61.6		18.2		0.5		0		7.6		68.0		0.5		0	
Filterer																						
Arctopsyche grandis															49.7	99.4						
Brachycentrus sp.													9.7	19.4	44.3	51.8			245.2	131.8	5.4	9.7
Hydropsyche sp.															20.5	32.4			23.8	29.2		
Parapsyche elis	20.5	29.2	176.0	313.2	67.0	79.9	9.7	19.4	106.9	163.1							2.2	3.2				
Pisidium sp.															3.2	5.4						
Simulium sp.							13.0	18.4			57.2	49.7	3.2	3.2	3.2	5.4						
Total	20.5		176.0		67.0		22.7		106.9		57.2		12.9		120.9		2.2		269.0		5.4	
Miner																						
Chironomidae			96.1	138.2	4.3	9.7	265.7	72.4			99.4	25.9	660.1	428.8	5.4	7.6	2.2	3.2	7.6	5.4	86.4	46.4
Lumbriculus sp.	3.2	5.4	61.6	123.1			32.4	42.1														
Tubificidae	9.7	11.9	7.6	10.0	11.9	19.4							3.2	4.3			10.8	16.2				
Total	12.9		165.3		16.2		298.1		0		99.4		663.3		5.4		13.0		7.6		86.4	
Predator																						
Atherix variegata							31.3	62.6					27.0	32.4					3.2	7.6		
Calineuria sp.									5.4	5.4					9.7	19.4	3.2	6.5			172.8	346.7
Ceratopogonidae																						
Chloroperlidae	3.2	6.5			3.2	7.6					6.5	11.9			9.7	8.6	3.2	4.3	6.5	5.4	3.2	6.5
Claassenia sp.																			305.6	353.2		
Dicronota sp.																						
Dytiscidae																						
Empididae															2.2	4.3						
Hesperoperla pacifica															177.1	353.2						
Hexatoma sp.																						
Hydracarina																						
Isoquenoides sp.															7.6	10.8	2.2	3.2				
Isoperla sp.	1.1	3.2																				
Megarcys sp.							20.0	40.0														
Muscidae																						
Nematoda																						
Perlodinae					1.1	3.2									6.5	13.0			3.2	7.6		
Perlesta sp.																						
Rhyacophila sp. A																						
R. angelita																						
R. hyaliniata			38.8	55.1									28.1	56.2								
R. vaccua									18.4	37.8	166.3	140.4	3.2	5.4								
R. vagrita			52.9	23.8			52.9	51.8														
R. verrula	1.1	3.2																				
R. vepulsa															3.2	5.4						
Setvena bradleyi	49.7	99.4	60.5	75.6			235.4	302.4	4.3	7.6												
Skwala sp.																	24.8	31.3	2.2	3.2		
Turbellaria	73.4	28.1	246.2	266.8	15.1	10.8	117.7	77.8	9.7	10.8												
Total	128.5		398.4		19.4		457.3		37.8		172.8		58.3		216.0		33.4		320.7		176.0	

Table 19 Biomass (mg dry wt/m²) of benthic macroinvertebrates collected from depositional areas in Summer 1982 (C=control, B=burn site)

	Teapot Creek (C)		Charcool Creek (B)		Dungo Creek (C)		Little Creek (B)		White Creek (C)		West Fork Little Loon (B)		East Fork Little Loon (B)		Indian Creek (C)		East Fork Indian Creek (C)		Marble Creek (C)		Little Loon Mouth (B)	
	x̄	SD	x̄	SD	x̄	SD	x̄	SD	x̄	SD	x̄	SD	x̄	SD	x̄	SD	x̄	SD	x̄	SD	x̄	SD
Scraper																						
Baetis bicaudatus	6.5	11.9	21.6	16.2	11.9	8.6			1.1	1.1	34.6	16.2					2.2	3.2	3.2	2.2	6.5	9.7
Baetis tricaudatus			41.0	29.2	18.4	8.6	70.2	52.9	4.3	5.4					16.2	20.1	14.0	21.6	10.8	1.1		
Cinygmula sp.	6.5	2.2	44.3	36.7	88.6	64.8	16.2	31.3	10.8	15.1	8.6	18.4			4.3	8.6	17.3	23.8				
Cleptelmis																						
Epeorus deceptivus					4.3	5.4	7.6	5.4			8.6	11.9					1.1	1.1				
E. longimanus					19.4	22.7					16.2	19.4					2.2	2.2				
Ephemerella doddsi					73.4	85.3											44.3	89.6				
E. flavilinea					19.4	14.0	11.9	22.7	3.2	6.5	22.7	25.9					2.2	5.4				
E. spinifera																						
E. tibialis					2.2	5.4			2.2	2.2	4.3	5.4			9.7	15.1	2.2	2.2				
Glossosoma sp.																						
Heterelmis					4.3	4.7			7.5	4.8							2.1	2.1				
Lara																						
Narpus									3.8	7.5												
Neophylax sp.					7.6	8.6			8.6	18.4												
Neothremma sp.	31.3	62.4	17.3	33.5			4.3	9.7							33.5	65.9			7.6	15.1		
Optioservus																						
Rhithrogena sp.																						
Stenelmis									2.2	4.3							3.3	3.8				
Zaitzevia									2.1	2.7												
Total	44.3		124.2		249.5		110.2		45.8		95.0		0		63.7		91.4		21.6		6.5	
Shredder																						
Limnephilus sp.																						
Psychoglypha sp.																			5.4	11.9		
Pteronarcys californica																						
Tipula sp.									1.1	3.2							37.8	74.5	1.1	2.2		
Yoroperla brevis	19.4	31.3					4.3	8.6														
Zapada oregonensis	7.6	3.2	1.8	3.2	14.0	13.0	3.2	5.4									1.1	3.2				
Total	27.0		1.8		14.0		7.5		1.1		0		0		0		48.9		6.5		0	
Gatherer																						
Ameletus cooki											19.4	6.5	3.2	6.5	3.2	3.2			5.4	9.7	14.0	18.4
A. similor	4.3	5.4	5.4	6.5	8.4	7.6			2.2	2.2	17.3	34.6					3.2	6.5				
A. velox			25.9	23.8	3.2	5.4	63.7	57.2			11.9	14.0	1.1	2.2	4.3	5.4						
Capniidae			6.5	7.6																		
Cleptelmis																						
Dixa sp.																						
Ephemerella grandis																						
Heterelmis					4.3	4.7			7.5	4.8							2.1	2.1				
Lara																						
Lepidostoma sp.							2.2	3.2														
Narpus									3.8	7.5												
Optioservus																						
Paraleptophlebia sp.	4.3	8.6																				
Rhyacophila acropedes	32.4	65.9							11.9	15.1					28.1	52.9						
Stenelmis									2.2	4.3							3.8	3.3				
Zaitzevia									2.1	2.7												
Total	41.0		37.8		18.1		65.9		29.7		48.6		4.3		35.6		9.1		5.4		14.0	
Filterer																						
Arctopsyche grandis	2.2	4.3																				
Brachycentrus sp.																			2.2	4.3		
Hydropsyche sp.																						
Parapsyche elsis					20.5	40.0									15.1	17.3	8.6	17.3				
Pisidium sp.																						
Simulium sp.							19.4	38.9			1.1	3.2										
Total	2.2		0		20.5		19.4		0		1.1		0		15.1		8.6		2.2		0	
Miner																						
Chironomidae			182.5	75.6			197.6	77.8			38.9	27.0	157.7	114.5	5.4	10.8	3.2	3.2			18.4	9.7
Lumbriculus sp.	76.7	72.4	11.9	14.0	6.5	13.0			293.8	543.2												
Tubificidae	19.4	38.9	61.6	41.0	27.0	21.6	81.0	110.2	4.3	6.5							21.6	16.2				
Total	96.1		256.0		33.5		278.6		298.1		38.9		157.7		5.4		24.8		0		18.4	
Predator																						
Atherix variegata																						
Calineuria sp.			6.5	11.9							11.9	22.7					110.2	214.9				
Ceratopogonidae																						
Chloroperlidae	9.7	14.0			22.7	20.5			6.5	13.0	5.4	10.8			8.6	5.4	9.7	7.6	3.2	3.2		
Claassenia sp.															3.2	6.5						
Dicronota sp.											3.2	7.6										
Dytiscidae																						
Empididae																						
Hesperoperla pacifica																						
Hexatoma sp.																						
Hydracarina																						
Isogenoides sp.					2.2	4.3											2.2	4.3				
Isoperla sp.																						
Megarcys sp.											1.1	3.2										
Muscidae																						
Nematoda																						
Perlesta sp.							1.1	1.1														
Perlodinae					1.1	3.2																
Rhyacophila angelita																						
R. hyalinata			1.1	2.2	8.6	13.0			22.7	44.3												
R. vaccua			28.1	38.9							64.8	19.4										
R. vagrita							2.2	4.3														
R. verrula					19.4	30.9	2.2	3.2														
R. vepulon					41.0	83.2	217.1	353.2														
Setvena bradleyi	7.6	15.1	4.3	5.4					1.1	2.2							2.2	4.3				
Skwala sp.																						
Turbellaria	138.2	109.1	467.6	100.0	30.2	19.4	16.9	14.6	20.5	23.8							14.0	9.7				
Total	155.5		507.6		125.2		239.5		50.8		86.4		0		11.8		136.1		3.2		0	

Table 20. Mean total number of invertebrates/m^2 collected in control and burn streams, summer 1982. The null hypothesis of no difference in mean numbers is accepted if t $\lesssim$ 2.447. (* = 0.05)

Depositional Total No. m^2	$\bar{X}$	S.D.	
Teapot Ck	591.3	424.8	t = 3.33*
Charcoal Ck	1285.2	282.6	
Pungo Ck	1055.7	308.3	t = 0.984
Little Ck	1260.9	406.1	
White Ck	405.0	172.5	t = 0.6731
W Fk Little Loon Ck	469.8	160.8	
Indian Ck	170.1	175.8	t = 1.0597
E Fk Little Loon Ck	348.3	372.5	
Marble Ck	54.0	26.5	t = 4.568*
Little Loon Ck	218.7	84.2	

Erosional Total No. m^2	$\bar{X}$	S.D.	
Teapot Ck	1152.0	449.2	t = 1.08
Charcoal Ck	761.4	560.6	
Pungo Ck	887.5	583.5	t = 2.905 *
Little Ck	1887.3	624.7	
White Ck	280.8	160.2	t = 5.05*
W Fk Little Loon Ck	839.7	218.7	
Indian Ck	469.8	203.9	t = 5.034*
E Fk Little Loon Ck	4498.2	1949.4	
Marble Ck	442.8	186.4	t = 5.326*
Little Loon Ck	1038.8	199.7	

depositional zones among control and burn streams. This contrasts strongly with the situation in erosional zones where, in every case but one, there are a significantly greater mean number of invertebrates per square meter in burn than in control streams.

Recovery from fire effects would not necessarily be expected to be observed by differences in taxonomic indicators. A priori, one might expect to see differences in functional group composition. Given non-normal probability distributions and heteroscedastic variances, the most appropriate statistical tests would incorporate differences in ranks for functional group composition and abundances. A non-parametric Mann Whitney U-test (Siegel 1956) was applied to functional group abundance data.

Scrapers (herbivores) and shredders, which feed on coarse particulate organic matter, were in statistically greater abundance in control streams than in burn streams (Table 21). Scrapers consistently make up between 45-55% of community composition in control streams, while shredders comprise between one to 13%. Gatherers (generalized detritivores and herbivores) predominate as a functional group in control stream erosional habitats. There are no strong trends for this functional group in depositional zones among control and burn streams. Filter feeders, which utilize transported fine particulate organic matter, were not statistically different among burn and control streams. Not unexpectedly, they do comprise a greater percentage of the community in erosional than in depositional zones. Miners are invertebrates which burrow into the substrate to feed. Miners comprise a much greater percentage in burn streams than in controls; this trend holds for both erosional and depositional habitats. Finally, as might

Table 21. Functional group composition (%) and total abundance (Nos/m^2) in erosional and depositional areas (July 1982). The bottom row is the probability that the samples are drawn from two populations of equal location (Mann-Whitney U-test).

	Scrapers		Shredders		Gatherers		Filterers		Miners		Predators		Total Nos.	
	Eros	Dep	Eros	Dep	Eros	Dep	Eros	Dep	Eros	Dep	Eros	Dep	Eros	Dep
Teapot Ck	49	13	15	13	5	9	2	1	8	13	19	51	989	567
Charcoal Ck	25	13	1	<1	3	7	4	<1	21	39	45	40	812	846
Pungo Ck	66	49	5	3	7	6	1	<1	10	24	11	17	879	1055
Little Ck	31	10	1	1	<1	7	2	1	58	59	8	22	1897	1252
White	73	42	0	1	6	18	3	0	1	13	16	26	330	407
E Fk Indian	43	34	1	2	4	7	2	1	33	33	17	24	467	493
W Fk L Loon	30	47	0	0	<1	5	15	1	43	37	12	10	760	470
Indian Ck	51	52	1	0	11	22	22	2	6	11	9	13	384	171
E Fk L Loon	6	1	<1	0	<1	1	<1	0	93	98	1	0	4500	494
Marble Ck	22	35	2	9	2	6	36	6	26	30	12	15	439	54
Little Loon	3	5	0	0	<1	6	1	0	96	87	1	1	1034	220
p =	.028	.016	.008	.008	.008	.1	.243	-	.008	.004	.17	.11	.048	.27

be expected a priori, there are no differences between control and burn streams with respect to the relative abundance of predatory invertebrates.

Although there are no statistically apparent differences in scraper biomass (mg/m^2) between control and burn streams (Table 22), shredders comprise a much greater percentage of total invertebrate biomass in control streams. Gatherer biomass is greater in control erosional zones and relative filterer biomass is greater in control depositonal areas than in similar burn substrates. Strikingly, miners make up the largest percentage in burn than in control streams, following their increased relative abundance in these sites (Table 21). Finally, there is no significant difference in total invertebrate biomass for either erosional or depositional zones among control and burn streams (Table 22).

Taxonomic richness, equitability and diversity are significantly greater (Mann-Whitney U) in control than in burn streams (Table 23) over both erosional and depositional habitats. The effect of a major washout on the East Fork of Little Loon Creek is apparent in the low values for these three biotic parameters for that stream. Of all the streams, Pungo and Indian Creeks have the highest taxonomic richness for the 1982 summer study.

Discussion

A. General

Fire is an important evolutionary force in ecosystem development, especially where the potential for periodicity (e.g., lightning, human activity) exists (Barbour et al. 1980). In forested ecosystems wildfire

Table 22. Functional group composition (%) and total biomass (mg/m^2) in erosional and depositional areas (July 1982). The bottom row is the probability that the samples are drawn from two populations of equal location (Mann-Whitney U-test).

	Scrapers		Shredders		Gatherers		Filterers		Miners		Predators		Total Biomass	
	Eros	Dep	Eros	Dep	Eros	Dep	Eros	Dep	Eros	Dep	Eros	Dep	Eros	Dep
Teapot Ck	46	12	11	7	7	11	5	1	3	26	28	43	462	366
Charcoal Ck	18	13	2	<1	1	4	19	0	18	28	43	55	927	920
Pungo Ck	22	54	<1	3	73	4	3	5	1	7	1	27	2106	462
Little Ck	62	15	1	1	3	9	1	3	13	39	20	33	2262	722
White Ck	41	11	0	<1	7	7	39	0	0	70	14	12	276	426
E fk Indian	65	29	0	15	21	3	1	3	4	8	10	43	327	319
W Fk L Loon	60	35	0	0	<1	18	17	<1	30	14	53	32	525	270
Indian Ck	40	48	24	0	1	27	12	11	1	4	22	9	971	132
E Fk L Loon	12	0	3	0	0	2	1	0	76	98	7	0	869	162
Marble Ck	4	56	8	18	<1	13	40	5	1	0	47	8	679	39
Little Loon	1	18	0	0	0	35	2	3	32	45	65	0	269	40
p =	.345	.075	.028	.014	.05	.557	.111	.008	.004	.004	.210	.345	.345	.345

Table 23. Taxonomic richness, equitability, and Shannon-Wiener diversity ($\log_2$) based on mean abundance data for erosional and deposition habitat (July 1982).

	Teapot Ck	Charcoal Ck	Pungo Ck	Little Ck	White Ck	E Fk Indian	W Fk L Loon	Indian Ck	E Fk L Loon	Marble Ck	L Loon Ck
Richness											
Eros	22	21	34	19	23	23	19	27	17	26	7
Dep	14	17	27	22	23	25	17	12	4	10	4
Equitability											
Eros	0.33	0.34	0.41	0.20	0.39	0.38	0.27	0.47	0.04	0.39	0.03
Dep	0.30	0.25	0.34	0.24	0.44	0.42	0.28	0.40	0.02	0.50	0.09
Diversity (H')											
Eros	3.26	3.28	4.05	2.23	3.28	3.38	2.54	4.02	0.53	3.43	0.34
Dep	2.74	2.45	3.36	2.44	3.84	3.73	2.49	2.95	0.15	2.87	0.71

probably represents an upper limit of disturbance for nutrient cycles (Tiedemann, et al. 1978). Many forested ecosystems have adapted to minimize adverse nutrient loss effects stemming from wildfires. Before fire suppression practices were widely implemented, it was unlikely that nutrient loss from an ecosystem had significant long-term detrimental effects on productivity (Richter, et al. 1982). Most likely, nutrient losses from burns are roughly equal to nutrient gains from burns in adjacent ecosystems (Clayton 1976), especially over long time periods. Frequently occurring fires preclude a buildup of large stores of dead organic material to fuel exceptionally hot burns. Hence, small, low intensity fires would cause less nutrient mobilization.

The role and effects of fire on terrestrial ecosystem nutrient budgets have been more thoroughly documented and described than for aquatic systems. Terrestrial plant material regeneration, plant succession, and maintenance of fire climax species have received considerable attention (Clayton 1976; Barbour, et al. 1980, Wright and Bailey 1982). Mechanisms of nutrient flux following a fire are more fully understood within terrestrial systems; few studies have attempted to discern the dynamics of nutrient movement from terrestrial to aquatic ecosystems.

Several factors limit critical interpretation of measurements made on this and other studies of fire effects on aquatic ecosystems. Lack of prefire data for most studies compared (Table 11) make it difficult to distinguish between fire effects and natural variation among burned stream ecosystems (cf., Schindler, et al. 1980). In this study, the lack of both fire intensity data and our knowledge of the precise distribution of fire within each burned watershed make specific

comparisons more judgmental in nature. Additionally, interpretations of measures made at one point in time (e.g., July, 1982) on a number of critical parameters may not reflect the full impact the Mortar Creek fire has had on the affected watersheds.

Generally, nutrient quantity reaching a stream after a fire is a function of the interaction among physical, biological and chemical parameters (Swanson 1981, Wright, Jr. 1981). Richter, et al. (1982) have identified fuel quality and quantity, soil properties, topography, climate, weather, fire frequency and intensity information as necessary to determine the effect of fire on an ecosystem. Nutrient transport across terrestrial/aquatic ecosystem boundaries will be a function of those above-mentioned parameters as well as the condition of post-fire terrestrial riparian vegetation.

Burning apparently alters nutrient partitioning between organic litter and mineral soil (Lewis 1974). Nitrogen, depending upon the fire intensity, can be volatilized from plants and litter and lost to the atmosphere (Richter and Ralston 1982). Phosphate is also volatilized in very hot fires (Barbour et al. 1980). Cations such as Ca^{2+}, Mg^{2+}, and K^{+} are mineralized and redistributed as oxides (Tiedemann et al. 1978). With time these oxides are converted to more soluble carbonates. Loss of the organic litter layer by burning reduces the high cation exchange capacity characteristic of organic matter, thereby removing a vital nutrient retention trap (Barbour et al. 1980, Woodmansee and Wallach 1981). A decrease in soil wettability increases surface runoff which effectively removes many dissolved nutrients. More ions are available for leaching due to alteration in soil ion exchange capacity. Soil ion exchange capacity is a function of soil texture,

organic content, clay content, porosity and annual precipitation (Stark, 1977). Soil pH can increase or decrease depending on the vegetation type extant after a fire (Likens et al. 1970); these pH changes cause cations to be more readily mobilized and therefore more easily leached. Anions do not seem to be as easily mobilized as cations; and they appear to be transported through soil more slowly than are cations (Stark 1977). For these reasons, anions are not as readily leached from the soil. It is difficult to quantify the effect fire may have on the rate of soil weathering (Wright 1976, Swanson 1981). Differential weathering between control and burn watersheds complicates the picture of the ion source area. Watershed soil type is an extremely important factor in determining the type and concentrations of ions available for transport to streams. McColl and Grigal (1977) determined that variation between burn and control streams was not adequately accounted for by burn alone where there were significant differences in soil type.

The season during which a fire occurs will largely determine nutrient amount available for export to streams. During spring fires, there is a steep moisture gradient between the forest floor litter layer and the underlying soil (Richter et al. 1982). Therefore, fires are not as hot and soil wettability is not significantly altered. Nutrients released by the fire are then rapidly taken up by herbacious plants before significant leaching occurs. Burns of this type make few nutrients available for transport and may actually enhance terrestrial system productivity (Barbour et al. 1980, Boerner 1982). On the other hand, autumn burns are usually hotter because the forest floor litter has lost a great deal of its moisture during the drier summer season. More complete and hotter burning decreases soil wettability and therefore contributes to increased runoff. Since most herbacious forest

forest floor plants have completed their growing cycle, few are present after an autumn fire to utilize the newly available nutrients. As a result, fall rains and spring melt runoff transport large amounts of nutrients into the watershed streams (Lewis 1974, Wright 1976, McColl and Grigal 1977, Stark 1977, and Schindler et al. 1980). Since the burn on the Middle Fork of the Salmon River occurred in late summer, nutrient loss would most likely be similar in nature to a fall burn.

Observations on Little Loon Creek drainage lead us to the strong conclusion that episodic storm events (spring and summer thunderstorms) are extremely important in influencing the nature of stream substrate and the composition of the resident fauna. In several locations, the stream had been extensively scoured; in other locations mass movement of soil and debris formed a new stream bank. Several other factors are responsible for nutrient transfer across the terrestrial/aquatic ecosystem boundary. Overland water flow, ground water flow and subsurface flow all transfer nutrients into aquatic systems (Wright 1976). Deposition of particles dissolved or suspended in rain water and translocation of particles by wind into streams and lakes (Clayton 1976) are other contributing mechanisms.

Overland flow of water is observed to significantly increase after deforestation (Johnson and Needham 1966, Likens et al. 1970, McColl and Grigal 1975, and Schindler et al. 1980). Differential overland flow rates between control and burn areas could increase the variability observed between control and burn streams. High runoff (e.g., spring snowmelt) transports substantial amounts of ions; however, ion concentrations will be inversely proportional to stream or runoff flow (Johnson and Needham 1966). Nutrient concentrations in burn streams may

increase if overland flow is the main hydrologic input (McColl and Grigal 1977); however, overland flow is transient and spatially discontinuous. Runoff reaches streams largely by subsurface flow through the soil. Subsurface flow is in intimate contact with the soil (McColl and Grigal 1975) and therefore more likely to have ions immobilized by ion exchange complexes.

A final factor which lends variability to the type of comparisons made in this study is time. Measurements on stream water chemistry for all studies compared (Table 11) were made anywhere from weeks to 40 years following the fires. With the passage of time, the number of significant differences in ion concentration between burn and control watersheds is reduced (Stark 1977). Stark (1977) found the most soluble ions to be the first to return to control levels. McColl and Grigal (1977) attribute the decrease in ion concentration to biological uptake by plants as they undergo rapid growth and recovery following a fire. Therefore, differences observed in stream water ion concentration between burned and unburned watersheds are probably best interpreted in conjunction with other potentially mitigating events.

B. Chemical

All measures of stream size are significantly correlated with each other (Table 7). From 36 percent (for volume discharge: stream order) to 96 percent (for stream order: log (stream link number)) of observed variation in all possible pairings of these variables was accounted for by the correlations. Underlying all these correlations is the statistically significant correlation each has with drainage area.

All stream size measures were also negatively correlated with

cation and anion concentrations (Table 7). Increasing discharge will dilute ion concentrations, providing the negative correlations, although potassium is a common exception. The relation between conductivity, alkalinity and major ions is positive and statistically significant (Table 7 and Fig. 4).

Since the trilinear graphs (Fig. 4) for major ions depict concentrations on a percentage basis, they illustrate relative rather than absolute chemical composition of the sample streams. As expected, relative ion composition at all sites was similar. Calcium and bicarbonate/carbonate are the predominant ions, while relative amounts of Na^{+}, K^{+} and Cl^{-} are small.

The ion concentration correlation matrix (Table 7), and similar matrices obtained using data from burn, control and mainstem sites, do not suggest any measured variables were affecting other variables in an unusual or unexpected manner. Factor analyses confirm the correlations with, commonly, three factors with variables grouping as: 1) cations and conductivity; 2) phosphate, usually with nitrate and an anion; and 3) stream order and link number.

Analyses of covariance evaluate variation in each ion concentration owing to main effects (control vs. burn), while controlling for the influence of one covariate, either stream order or log (stream link number). Because regression slopes of ion concentrations versus either covariate were not statistically different between burn and control sites, the model assumption of similar relations among ion concentrations and the covariates, stream order or log (stream link number), under different main effects (burn or control) was accepted.

With the cautionary notes mentioned in the general discussion (above) kept in mind, the following conclusions arise with respect to stream chemistry: First, there seems best agreement among our study and others on the nutrients phosphate and nitrate. If the effect of "burn" on nitrate yield (Table 8) is taken as significant (at $\alpha = 0.057$), then all studies reviewed (Table 11) find yield of these ions to be greater in streams draining burned watersheds.

Second, there appears good to fair agreement concerning the major anions, bicarbonate/carbonate (alkalinity), sulfate and chloride. Our results and those of Likens, et al. (1970) show no effect on sulfate yield from burning. Chloride yield is increased after burning (or cutting), but results are less conclusive for chloride concentration. Alkalinity is a minor component in surface waters studied by Likens, et al.; hence, direct comparisons between our data and theirs are not generally appropriate. None of the other studies measured yield of alkalinity; hence, the increase following burning which we observed cannot be compared.

Finally, least agreement is found among results for cations. All studies found burning or cutting to increase both concentration and yield of Ca^{2+} (however, see Richter, et al. 1982). We and two other studies found Mg and Na concentrations to be unchanged by burning; Likens, et al. (1970) found these to increase upon cutting. Our results for K^+ concentrations agree with Richter, et al. (1982) in that no differences are seen upon burning; however, the other studies generally report an increase in concentration and yield following burns.

C. Biological Integration

Chemical and physical parameters including stream order, log (stream link number), discharge, alkalinity, conductivity, SO_4, PO_4, Ca, benthic chlorophyll-a, biomass, and percentage organic of stored benthic material were used in correlation and forward stepwise regression analyses. Biological variables used included mean total invertebrate abundances in depositional and erosional zones, mean total invertebrate biomass, and species richness and diversity. The resulting equations stemmming from regression models are not meant to derive "cause and effect" relationships; rather, they are intended to provide an equation showing the joint covariation among "dependent" and "independent" variables, and to support the correlation results.

With respect to depositional zone invertebrates in both burn and control streams, both standing crop (DEPMASS) and abundances (DEPABUN) were negatively influenced by stream size. The regression equations support the correlational analyses and are as follows:

DEPMASS = 653.79 + 2.1 (CHLA) - 255.1 (LOG LINK)

DEPABUN = 639.9 = 204.8 (ORDER) + 1985.8 (LOG ALKA)

where

CHLA = chlorophyll-a biomass

LOG LINK = Log(stream link number)

ORDER = stream order

LOGALKA = Log(alkalinity)

The equation for invertebrate abundance accounts for 76.2 percent of the observed variation; the equation for biomass of depositional zone invertebrates accounts for 78.1 percent of the observed variance in

invertebrate biomass.

Invertebrate abundance and biomass in erosional zones for all streams are quite variable. No variables arise to explain a measureable percentage of the observed variation in biomass. Invertebrate abundance (EROABUN) is significantly, positively, albeit weakly ($R^2 = 0.58$) explained by the diversity of depositional zone invertebrates (=DEPOHPR). The regression equation is: EROABUN = 3145.7 + 797.4 (DEPOHPR). Taxonomic richness in erosional zones (ERORICH) is a function of both the community diversity (EROHPR) and biomass of chlorophyll-a (CHLA). The equation explains 84.8 percent of the observed variation in taxonomic richness: ERORICH = 11.8 + 4.3 (EROHPR) + 1.53 (CHLA).

The study has shown that an important control on the nature of a stream community is the influence of storms on slope stability and washout. Substrate permeability is not different among burn and control streams, a fact substantiated by an independent USFS study on Rapid River. Moring (1982) found gravel permeability to decrease following extensive clear cutting within a watershed. In that study, increased stream flow (not from storm events) enhanced sediment deposition. Timing of elevated runoff is an important parameter influencing benthic sediment concentrations.

Minshall, et al. (1982) noted (pg 116) that grazers should increase in burn streams, given no disruptive spates and/or storm events. Three years after the 1979 burn, we find only miners in much greater abundance in burn than in control streams. Scrapers (herbivores) are not as extensive as would be hypothesized given the open canopy, increased incidence of light, and much greater biomass of chlorophyll-a in burn

streams. It may well be the unstable, shifting nature of the substrate, not yet in equilibrium with post-fire conditions, precludes the stronger development of scraper and filterer functional groups. The influence of spates is visually apparent, but remains difficult to quantify.

A fire management program designed to mitigate influences on streams within the Middle Fork of the Salmon River drainage basin will require full information on fire intensity and its spatial distribution within the burned watersheds. Further, it becomes apparent that monitoring prior to, during and after spring runoff is minimally necessary to assess the effects of slope, soil disturbance, and nutrient input within burn streams. If at all possible, an intensive investigation of a fewer number of contrasting tributary basins (e.g., Charcoal Creek - Teapot Creek, Pungo Creek - Little Creek, and Marble Creek - Little Loon Creek) would include measures on these systems prior to and after rainstorms.

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